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Insect Invaders in Hawaii During and Since World War II

OTTO H. SWEZEY, *Experiment Station, Hawaiian Sugar Planters' Association, Honolulu*

This brief paper deals with 31 species of insects which became established in Hawaii during, and since World War II. There are seven moths; 13 wasps, ichneumon-flies and chalcid-flies; three beetles; three bugs; three Diptera, a grasshopper and a cricket. Several aphids and thrips which were first recorded in this period, are not included, as there may be some uncertainty as to whether they might not have been previously established. Four of the moths are definitely injurious; a fruitfly is notoriously destructive; six of the wasps are distinctly beneficial as they prey upon caterpillars and crickets. The larger number of this list are of little or no importance. Many of these insects were first observed in the Pearl Harbor area, which could be accounted for by reason of the excessive increase in shipping and airplane arrivals at this military center, and the consequent great difficulty of carrying on quarantine inspections. This list does not include the large number of "interceptions" by the increased force of entomologists in their quarantine inspections.

LEPIDOPTERA.—*Anacamptodes fragilaria* (Grossbeck).

This geometrid moth made its appearance in August, 1944, when caught in a light-trap operated by the U. S. Navy at Pearl Harbor. Then in February, 1945, it was reared from caterpillars found feeding on *Nicotiana glauca* in a Honolulu garden; and the same month a survey disclosed its presence widely distributed on the island of Oahu; and the caterpillars were found feeding on 29 kinds of trees and plants. Trees of the Leguminosae, especially the algaroba, were most severely attacked and often there was considerable defoliation. The whitish moths with black markings became conspicuous in daytime as they rested with spread wings on the bark of trees and on buildings, and at night being attracted to lights. There was some alarm lest it might become a destructive pest, but it was on the decline the following year when the caterpillars were preyed upon by several natural enemies. This moth is a native of southern California. It soon spread to the other islands of the Hawaiian group.

Achaea janata (Linn.) The first moth of this large agrotid was found at the Experiment Station of the Sugar Planters Association in Honolulu, December 1, 1944. Early in 1945 it began coming to lights in Honolulu, and in March it was found to be distributed widely on Oahu, its caterpillars feeding on many kinds of plants. The castor oil plant and *Euphorbia* weeds were the most conspicuous host plants, as they were often found completely defoliated. During the year, it was found spread to the other islands. Several natural enemies began working on it: egg-parasites, ichneumonids and tachinids. It was soon greatly reduced. This moth is widely distributed in Pacific Islands, Australia and the Orient.

Amyna natalis (Walker) This smaller agrotid was first collected in a Navy light-trap in the Pearl Harbor area, several times in May, 1945. Then later in the year, was collected in light-traps operated at other locations. Early in 1946, it was reared from slender caterpillars feeding on *Sida cordifolia*, a shrubby weed in the lowlands, and on a few other related weeds It has not attacked any economic plants. It is known in India, New Guinea, Australia, Fiji, Tonga and Samoa.

Polydesma umbricola Boisduval This destructive agrotid was first found June 4, 1945, when caterpillars and pupae were found in debris at the base of monkeypod

trees in a suburb of Honolulu. Some moths issued soon thereafter and the species was readily identified as one reared in Guam in 1936. It is known to occur in Africa, Madagascar, India, Ceylon, Burma, Andaman Islands and Society Islands. On Oahu, it soon spread throughout the island, and its caterpillars caused considerable defoliation to the monkeypod trees, one of the large spreading shade tree of Honolulu and the rural districts. There was conspicuous dieback of branches resulting from this defoliation. Large-scale spraying was resorted to in attempts to check the pest. Natural enemies also played a part, so that the pest ceased to be an important menace in succeeding years.

Elaphria nucicolora (Guenée) This is a medium-sized brownish agrotid moth, first collected in light-trap at Pearl Harbor June 5, 1945. In December 18 to 26, moths were taken in light-traps at Wheeler Field and in 1946, at various times, it was taken in light-traps at widely distributed locations: Waipio, Kalihi, Wahiawa and Kahuku, all on Oahu; and in June 1947 it was taken in light-trap at the Hawaii National Park, 4000 feet elevation on the island of Hawaii. Nothing has yet been learned of its habits here, as the only specimens seen have been those from light-traps. No caterpillars have been observed. The moth is known in Texas, Florida, Bahamas, Jamaica, Peru and Brazil. In Florida it is included with other moths which "have assumed cutworm habits in sugar cane." Hence, there is a possibility that it may yet be found in Hawaiian cane fields.

Trichochlea postica Smith This is another immigrant agrotid moth that is known only from light-trap collections at various times in the Pearl Harbor area from September, 1947 to February, 1948. The species is known in southern California.

Stictoptera subobliqua (Walker). This is the most recent immigrant agrotid moth. Caterpillars were first found feeding on foliage of a mammee-apple tree in the heart of Honolulu in March, 1948. As soon as moths were reared, the species was recognized as one that was reared by the writer from *Ochrocarpus excelsus*, a forest tree in Guam, in 1936. In Honolulu and rural districts of Oahu, caterpillars have been found feeding on the following trees: *Calophyllum inophyllum, Garcinia xanthochymus, Mammea americana,* all in the family Guttiferae, and also on *Clusia rosea.* The caterpillars feed on the newer foliage and thus cripple the growth and spoil the appearance of these shade trees. This moth was described from Ceylon. It is also known in India, Singapore and British New Guinea. It is quite variable in wing markings and coloration: shades of brown and ochreous with fuscous markings, and often in the females there is an oblique white line across the middle of the forewing.

HYMENOPTERA.—*Polemistus luzonensis* Rohwer. This is a tiny wasp, first found June 30, 1945 on the grounds of the Experiment Station, H.S.P.A., in Honolulu. It occurs in the Philippines; and presumably stores its nests with aphids; hence, is beneficial.

Liris aurata (Fabr.) This beautiful larrid wasp was first collected in the Pearl Harbor area, September 9, 1946. It preys on crickets of the genera *Gryllus* and *Gryllodes*, and, hence, is beneficial. It is known in China, Japan, India, Philippines, Formosa, Guam and Africa.

Eumenes latreillei petiolaris (Schulz). This large black and orange eumenid wasp was first collected in September, 1946 in the Pearl Harbor area, and has since become widely spread on Oahu. It is conspicuous by its large size when seen about gardens in search of caterpillers, or feeding on flowers. Their mud nests are also conspicuous as they are constructed on the walls of buildings and posts, of large mud cells placed in a vertical line, and composed of three to seven, or more cells. So far as has been observed the cells are stored only with caterpillars of the *Anaccamptodes* moth which had become so abundant two years previously—six to eight caterpillars per cell. The wasp is known in New Guinea. It is a very valuable addition to the insect fauna in Hawaii.

Eumenes campaniformis (Fabr.). This black and yellow eumenid was first found in the Pearl Harbor area, October 16, 1946. It is another beneficial wasp which collects caterpillars for its larvae. It has not increased to the extent of the preceding species. It has been recorded from Java, Philippines, Queensland and Yule Island, New Guinea.

Eumenes pyriformis philippinensis Bequaert. This large dull black eumenid was

first found October 17, 1946, in the Pearl Harbor area. Like the other eumenids, it is also a caterpillar hunter. It has not yet become as common as the *E. petiolaris* above. It is known in the Philippines.

Tachysphex bituberculatus Cameron. This larrid wasp was first collected in Honolulu, September 11, 1946. It is still rare and its habits are not well known. It occurs in the Philippines.

Chalybion bengalense (Dahlbom). This sphecid wasp was found first at Nanakuli, Oahu, April 3, 1947, and on April 22 more specimens were collected about a log pile in the same locality. It is a widely distributed species, occurring in Europe, Africa, India, Ceylon, Japan, Java and the Philippines.

Pison sp. This wasp was first captured November 2, 1947, on the Kawaiiki trail in the Koolau Mts., Oahu. Very little is known of it yet.

Leucospis affinis Say. This chalcidid was first taken April 18, 1947, at Nanakuli, Oahu, from a pile of timber. It is known as a parasite of leafcutter bees, and distributed in America from Canada and United States to Mexico, Cuba and Brazil. No doubt there was a bee's nest in some of the timber at Nanakuli.

Hemiptarsenus semialbiclavus (Girault). This eulophid was first noted in November, 1946, as a parasite of *Phytomyza spicata* Malloch, the corn leafminer, and widespread on Oahu wherever its host was found. This parasite was described from Queensland. The writer reared it abundantly from the corn leafminer in Guam in 1936, also from some other leafminers.

Chrysoplatycerus splendens (Howard). This encyrtid was reared from mealybugs, *Pseudococcus citri* and *P. maritimus* in June, 1946. It was originally described from California.

Urolepus rufipes (Ashmead). This pteromalid was first observed in the Pearl Harbor area in August, 1946, as adults were crawling over puparia of the ephydrid fly *Ephydra gracilis* Packard, and is probably parasitic on this fly.

Eurytoma sp. This eurytomid was first found on the grounds of the Experiment Station, of the Sugar Planters Association in Honolulu, May 11, 1945. It was reared from egg cases of the spider *Latrodectus geometricus*, and later on it was recovered from the egg cases of *Latrodectus mactans*, the black widow spider, collected at Lualualei, on the west coast of Oahu, May 31, 1945. The larvae feed on the spider eggs in the egg cases. Many were reared for distribution, and it is expected to become a valuable check on the black widow spider.

DIPTERA.—*Dacus dorsalis* Hendel. This oriental fruitfly was first known in Hawaii when it was reared from mangoes in Honolulu, May 10, 1946. It was soon found to be widespread on Oahu, and later in the year spread to the other islands. Mangoes, avocados, breadfruit and guavas are severely attacked by this fly; also bananas and papayas if allowed to ripen on the tree. The practice of picking these fruits green for market saves them from becoming infested. This is very fortunate as they are the most abundant year-around local fruits in the markets. The local entomologists have cooperated in obtaining host records for this fly, and it has already been reared from fruits of nearly 100 plants, including edible fruits and fruits of ornamental and wild plants and weeds. It is apparently a worse fruit pest than the Mediterranean fruitfly. It is prevalent in the Orient: Japan, Formosa, China, the Philippines, etc.

Ephydra gracilis Packard. This small ephydrid fly was first collected in a light-trap in the Pearl Harbor area in April, 1946. On July 23, it was found breeding in millions in salt-water ponds near the Moanalua Gardens in a suburban area between Honolulu and Pearl Harbor. The larvae live suspended in the water, and occur very abundantly in Great Salt Lake, Utah; in Salton Sea in California and in other coastal regions of California.

Phytomyza spicata Malloch. This agromyzid fly was first noticed in November, 1946, as a leafminer in grasses. It has been found breeding in 14 kinds of grass and also in young corn plants. In one instance it was found mining the leaves of young cane seedlings. It is now widespread on Oahu, and is apparently kept well controlled by three kinds of eulophid parasites, the most important one being *Hemiptarsenus semialbiclavus* (Girault). This parasite was found controlling the leafminer in corn on Guam in 1936. Besides Guam and Hawaii, this corn leafminer is known in Fiji and Samoa.

There are also first records during this period of several small Diptera of which

there is uncertainty as to whether they might have been previously established, and had remained unobserved until now. No *Anopheles* mosquitoes have yet succeeded in invading Hawaii. Light-traps have been operated in the Pearl Harbor area purposely to gain prompt knowledge if any should become established.

COLEOPTERA.—*Rhipidius pectinicornis* Thunberg. This curious rhipiphorid beetle was first observed as an "interception" on an Army plane from the South Pacific, January 25, 1944, when it was dissected out of an adult roach: *Blatella germanica.* In the summer of 1945 it was captured several times in light-traps in the Pearl Harbor area. It is a European species which has been introduced into the United States.

Chrysobothris sp. This is a buprestid beetle first collected in Honolulu, June 8, 1946, on a lawn near a mango tree. It is considered to be a Philippine species.

Xylotrechus colonus (Fabr.). This cerambycid beetle was first taken at Nanakuli, Oahu, April 3, 1947, on the window of a store. It is known in the eastern United States, where it attacks many trees, as birch, oak, hickory, chestnut, ash, beech and maple.

HETEROPTERA.—*Graptostethus manillensis* (Stål) This conspicuous red and black lygaeid bug first came to notice in Honolulu, January 18, 1943, when found in a package of seed capsules of *Ipomoea tuberosa* being inspected for shipment to the mainland. During the year 1943, an accasional adult specimen was taken on foliage of various plants and on windows in various parts of Honolulu. In a later study of material collected in wind-traps in pineapple fields at Kunia, Oahu, in the summer of 1942, two specimens of this bug were found. In 1943 they were taken more numerously in traps in this locality, and were found feeding on sweet potato and morning-glory foliage. In 1944 this bug became more widely spread on Oahu and was also found on Kauai; and in 1945 it had reached Maui. The only plant on which the eggs and younger stages have been found is the morning-glory *Ipomoea tuberosa.* It has not become a pest. This bug is known from Luzon, Negros, and Leyte in the Philippines.

Lygus elisus VanDuzee. This small lygaeid was first taken in a light-trap, July 9, 1947, in the Pearl Harbor area, and it was found breeding extensively on *Chenopodium album* in the vicinity of the trap. It is not yet known to have spread from the locality. It is a potential pest, for in western United States it is known as a pest on beans, cotton, alfalfa and sugar beets.

Melanolestes picipes abdominalis (Herr.-Schaeffer). This large reduviid bug was taken in a light-trap in the Pearl Harbor area, October 30, 1947. It is a widely spread bug in the United States.

ORTHOPTERA.—*Paraidemona mimica* Scudder. This wingless grasshopper was found established among grass and weeds near a light-trap operated in the Pearl Harbor area, July 5, 1945. Apparently it has not spread from the locality, or become a pest. The species was described from Texas, and apparently there are no records of its being of economic importance.

Metioche vittaticollis Stål. The first specimen of this small cricket was collected in a Honolulu garden late in 1944. Then, on June 4 and 6, 1945, it was taken in a light-trap in the Pearl Harbor area. Later, it became widely spread on Oahu and appears to be of no ecomonic importance. It occurs on other Pacific islands.

From the foregoing account of these 31 species, it is evident that 11 have come from the mainland, U. S. A.; 6 from Guam; 5 from the Philippines; 5 from other Pacific islands, or the Orient; while the origin of the remaining 4 species in uncertain.

Insect Surveys in Relation to Quarantine and Control of Insect Pests

E. O. Essig, *University of California, Berkeley*

Thorough insect surveys should be as much a part of the work of entomologists as are systematic entomology and economic entomology. As a matter of fact neither of these latter fields can be properly conducted without collecting and surveying the insects of the areas involved. The insect collector is constantly engaged in insect survey work. By going through the large collections of the country, it is possible to gather much information from locality and date labels. Unfortunately, the early collectors were not concerned with immediate localities, and many of the early surveys made in this state simply list the insects from California. The purpose of this paper is to indicate some of the values accruing from more intensive and exacting insect surveys. Present day insect surveys require the reporting of every particular locality where the insect pests are collected. In view of the tremendous insect fauna of California, it will probably take many years of the most intensive and well directed work to map out the distributions of all of the insects that occur here.

Because of the many importations of insects into the state, it is very doubtful if we now have more than a scant knowledge of the distribution of all of the potential pests. The control of insects, and especially the attempts at extermination of serious imported species, has brought to the public attention the importance and great value of definite and continuous surveys to determine from day to day the presence and economic importance of every insect species that may occur within our borders.

The first noticeable insect survey that I have been personally acquainted with, was one conducted in Los Angeles County in the Claremont-Pomona area. This systematic-economic survey was prompted by the appearance and very destructive capabilities of the citrus mealybug which appeared in tremendous numbers in citrus orchards of southern California during the period 1905 to 1910. This insect was most injurious along the coast from San Diego to Santa Barbara. Many of the orange and lemon orchards were rendered unfruitful for a period of from 1 to 5 years and control measures, as then known, were of little value in stopping the depredations. On the suggestion of Professor A. J. Cook, then President of the Claremont Pomological Club, and Professor C. F. Baker, both of Pomona College, the aforementioned club sponsored a survey of the citrus orchards in the Claremont-Pomona area in order to find out if any serious pests were present. The work was supervised by Professor C. F. Baker who selected a group of five or six older students in Entomology and outlined a tree-to-tree inspection. Every orchard in the area was mapped and carefully inspected tree by tree. The survey was made during the years 1908 and 1909, and chiefly during the fall and winter and spring months. Altogether, 2 years were required to complete the task of inspecting approximately 2000 acres. This survey brought to light the following information:

1—The citrus mealybug was discovered in a number of orchards which were promptly fumigated until the insect disappeared.

2—The citricola scale was first discovered and reported as the long scale in an orchard just south of Claremont. It was promptly dealt with and the insect did not again appear in this area. It was found several years later in the Riverside County and also in the upper San Joaquin Valley citrus orrchards where it still exists. R. S. Woglum later reported that he found this scale in 1907 but thought it was the soft brown scale.

3—The presence of red and yellow scale was found in a number of orchards thought to be free from these pests. Hydrocyanic acid gas fumigation was the only remedy available and was not entirely effective in checking these insects.

4—A much wider distribution of black scale was revealed in these orchards than had been suspected.

5—The chaff scale was again noted on a single orange tree in the city of Pomona. This scale was later found to be of some importance in Ventura and proved to be a

species especially difficult to control.

The results of this survey were given fairly wide publicity and many of the counties conducted similar surveys soon afterwards. The type of tree-to-tree survey became a standard practice and was a very efficient means of determining insect distribution throughout the state.

It might be pointed out here that an extermination survey was conducted in northern California in connection with the attempted extermination of the citrus whitefly at Marysville and Oroville during the years 1907 and 1908. The object of the survey was eradication which was quite different from the orchard survey conducted a few years later. Nevertheless, it was just as important, and although the objectives were not wholly accomplished, they indicated that an insect could be eradicated if sufficient financial aid and proper legal authority could be obtained.

INSECT SURVEYS.—Insect surveys may be classified into two groups: I—Systematic and II—Economic.

SYSTEMATIC.—Systematic surveys are quite as important as the economic surveys. They might appropriately precede the economic surveys. Such procedure would involve:

1—A careful survey of entomological literature and other records. Entomological literature is extremely voluminous and such a survey would require a considerable amount of effort in order to be at all complete. Fortunately, there are many indices, catalogues, and other available sources of information. Such a project would entail a careful, almost page by page survey of systematic entomological literature, dealing with the particular insects and areas involved.

Entomologists frequently make fragmentary surveys in preparing monographs of special groups of insects and their publications are quite readily available. Even at this time, a number of such surveys are being made in specialized groups.

2—Insect collections: Another very important source of information is to be found in insect collections. These collections may be widely scattered and are not always readily available. Under such circumstances, it may also be difficult to enlist the services of disinterested parties to collect these data. Therefore, it would be necessary to send specialists to check the important collections of the country in order to find out what they may contain from California. In such collections, it is likely that many very important discoveries may be made which would give valuable clues to California insects that may have been overlooked by local collectors. In our state, the large, readily available collections in the California Academy of Sciences, the Southern California Academy of Sciences, the various universities, colleges, and museums are of first importance. Other collections far afield such as those in the U.S. National Museum, the American Museum of Natural History, the Philadelphia Academy of Sciences, and many others, contain material collected in California from earliest days to the present time by entomologists who sent material to these sources for determination and deposit. Since the records of these insects are not always published, they may remain unknown to those in whose domain they were taken.

Throughout California, there are many private insect collections which should also be studied. All of these may contain native introduced insects which have not been taken by those most interested in such species. Boy Scout and 4-H Club collections frequently disclose very interesting and often important economic insects. Since most entomologists belong to some club or organization, it would not be difficult to locate most of these collections and it is almost certain that the owners would be pleased to have them examined.

ECONOMIC SURVEYS.—*Reasons:* The most important reason for these surveys is to find out all the insects in a given area and to locate as quickly as possible any newly introduced serious pest that may have gained a foothold in the state, and to enable small infestations of such pests to be rather easily and promptly eradicated without great expense. When we realize that up to the present time approximately 250 important economic insects and other pests have been introduced into California it is not at all unreasonable to believe that similar new insects may continue to appear. Within the last few years, the citrus white fly, the Oriental fruit moth, the grape leaf skeletonizer, and the Mexican bean beetle, have all appeared unexpectedly within the boundaries of the state.

PURPOSES: The real purposes of these surveys are:

(1)—To ascertain an up-to-the-minute list of all species of suspected injurious insects that may occur within the state.

(2)—To study their identity, abundance, habits, and relative importance in their natural abode as well as in their new habitat.

(3)—To ascertain as nearly as possible the local ecological conditions, including climate, available hosts, natural enemies, and possible control of such introduced species.

VALUE: The value of these surveys may be realized in great savings to the agriculture and public health of the entire country. If more information had been available concerning the potentialities of the citricola scale when it was first noted in California in 1907, it could have been readily and cheaply eradicated. The early introductions of the black, red, purple, and other scales could have been effectively eliminated. I have been informed that the Oriental fruit moth was discovered during the routine work of a survey for the Mexican fruit fly in the fall of 1942. Had the insect been found earlier, the thousands of dollars spent in surveying and restricting its spread could probably have been reduced to a small fraction of the amount required. The delay has now made it practically impossible to insure the eradication of the insect. Incidentally, too, the citrus white fly was discovered in southern California in connection with the survey of the olive scale. The Mexican bean beetle was first reported by a laborer to a crew inspecting for red scale.

CONDUCT: Thorough insect surveys may be conducted by the federal government which has already had experience with gypsy and brown tail moths, the Japanese beetle, the European corn borer, the Mediterranean fruit fly, the sweet potato weevil, the white fringed beetle, the pink bollworm, and other very serious pests that have been introduced, and became sufficiently destructive to warrant the costs of suppression and eradication. Although not all of these insects have been completely eradicated they have been slowed down and restricted in their dispersion, some of them have been kept in quite close confinement to the original infested areas, and the Mediterranean fruit fly was completely wiped out.

The federal government is the only authority able to conduct insect surveys in all the various states in the Union. This authority makes it possible to survey areas for pests that are of little importance to the states inspected, but of very great importance to other parts of the country. A thorough well-organized insect survey of the entire country would no doubt reveal some very surprising and important information concerning the presence, distribution, and economic status of many unknown or little-known native and foreign insect pests. Our interest in such a national survey might well be made known to the Chief of the Bureau of Entomology and Plant Quarantine.

THE STATE: Many local insect problems are left for the states to handle. I have already mentioned a number of these. They have all been very expensive. Some of these insects have been eradicated but most of them are still in the process of encirclement and elimination. The state, being a small unit, is in position to survey its own agricultural areas and to deal with the pests summarily when found.

THE STATE NURSERY INSPECTION: This nursery survey has contributed a great deal to the knowledge of insect pests in California and has enabled prompt action in the restriction and destruction of many pests and has prevented their wider distribution throughout the state.

The insect survey, now being conducted in California by the State Department of Agriculture, will greatly strengthen this type of work. Its value and accomplishments will, of course, depend upon the financial support and continuity to enable the work to be done thoroughly and rapidly. It is certainly a great step in the right direction and I am sure it will pay large dividends to the entire state; perhaps to the extent of millions of dollars.

THE COUNTIES: Insect surveys in the counties have been conducted over a period of many years, but for want of financial support they have been more restricted and specialized in their scope. The inspection of agricultural properties by the county officials has added much to the knowledge of insect pests in California. The employment of entomologists by these counties to determine insects that are frequently discovered, also greatly

aids in the general survey work for the whole state.

INSTITUTIONAL SERVICE: Insect collections which are constantly being accumulated at the University of California add much to the knowledge of insect distribution in the state. It also correlates this knowledge somewhat with the insects of the Pacific coastal areas outside the state. The insects collected represent both economic and systematic species. It often happens that some of the insects that are thought to be of no economic value often turn out to be of very great significance when unexpected incipient outbreaks of them occur. During the summers, special field groups of students and staff members collect all available insects in certain circumscribed areas. These specimens are mounted, determined, and preserved for present and future study. Unfortunately, the State of California is so large that this type of survey work is extremely slow and we are in great hopes that funds may become available so that representatives of all of the insect species may be collected, preserved, and studied. There is every reason to believe that in many of the out-of-the-way places, important introduced insects may be found, and such surveys might yield very valuable and timely information.

Institutions like the California Academy of Sciences, universities and colleges, and entomological and natural history societies may aid greatly by participating in these surveys and in the determination of the insects collected. The combined endeavors of all of these entomological organizations have already resulted in affording a great deal more knowledge and protection to the agriculture of California than is realized. The very fact that they have been able to accomplish so little is indicative of the enormity of the task and of the need for pushing the survey work more forcibly.

PERMANENCE: Insect survey work has had a sort of permanence in the past through the endeavors of private collectors, institutions, and governmental agencies which have been collecting insects throughout the years. The chief difficulty now lies in the fact that these surveys have not been correlated and their accumulated results made known. What is now really needed is a well directed, adequately financed, cooperative effort. This effort might well be directed by existing state agencies and adequately supported state funds. The whole program should be put on a permanent basis with a sufficient number of competent inspectors to cover the entire state, not only once—but continuously. Not all insects appear in abundance every year. Certain species may disappear almost completely under unfavorable climatic conditions and re-appear in another year in tremendous numbers. Over a period of years it is likely that most of the common native insects would occur in sufficient numbers so that they would not escape the trained eyes of the inspectors who should be in the particular locality at the favorable time.

New insects: New insects are likely to be continuously introduced into the states by man, through commerce and travel; by natural means, such as high winds which often carry insects for hundreds of miles; by birds which may migrate long distances; by other insects which carry smaller ones on their bodies; and by streams and ocean currents which may carry objects infested by insects. There are also many other ways by means of which insects may be introduced into any distant area.

CARE OF SPECIMENS: The insects collected should be properly identified and cared for in well-arranged and readily accessible and well-preserved insect collections. Technicians are required to do this work. Such specially trained individuals are to be likened to the technicians in a well-organized hospital or any other technical institution. The information thus amassed and preserved may be studied and the results published as deemed necessary.

SUPPORT: Naturally, these insect surveys cannot be conducted unless they are adequately and regularly financed.

In addition to the survey work, financial support and personnel should be provided to conduct the necessary clean-up and extermination program following the discovery of a new and serious pest.

INSECT PESTS IN FOREIGN COUNTRIES: More information should be made available concerning the presence and distribution of injurious insects in foreign countries. In 1917, the Bureau of Entomology, United States Department of Agriculture, issued a *Manual of Dangerous Insects Likely to be Introduced in the United States through Importations.* This very valuable

bulletin has long been out of print. It is now being rewritten by the Bureau and will soon be made available. Some action might well also be taken to compile information from foreign countries on injurious insects that might possibly be introduced into this country. A knowledge of the life histories, host range, climatic tolerance, degree of damage, and susceptibility to control, would be most helpful in dealing with such species as might be introduced and established in this country.

INSECT SURVEYS IN RELATION TO QUARANTINE.—The chief objective of economic insect surveys is to secure the information necessary to establish justifiable plant and insect pest quarantines.

One of the great difficulties in securing prompt action in establishing quarantines and in organizing extermination programs has been occasioned by the lack of definite information concerning the economic status of the insect pest; its local and world distribution; host plants; and susceptibility to control.

Insect surveys could accomplish much in supplying a great deal of this information.

In conclusion, I would emphasize that *prompt action* is paramount to success in the eradication of any introduced insect pest. Such action can never be accomplished unless adequate *funds are available for such emergencies.*

SUMMARY.—Insect surveys are important to all entomologists making insect collections, writing technical papers, enforcing quarantine regulations and in conducting insect pest control and extermination programs. They should include thorough surveys of the cultivated and wild areas and of insect collections and all published reports and records.

Such surveys form a basis for legislative action and insurance against large outbreaks of serious native and introduced insect pests.—7-14-48.

Mites of Economic Importance in the Pacific Northwest[1]

R. L. WEBSTER

Investigators on pest control were fortunate in being able to obtain sufficient quantities of DDT for several years before this new insecticide was made available for general use to fruit growers. Consequently, much valuable information concerning the advantages and limitations of DDT were obtained in advance.

In the Pacific Northwest, DDT was investigated by the members of the Western Cooperative Spray Project during the years 1944 and 1945. In a statement prepared by this group January 24, 1946, the following remarks were made: "DDT has proved very effective for codling moth control, but whenever used, spider mites and woolly apple aphids have developed in serious numbers. For this reason it is not recommended on apples and pears."

In 1947, after 3 successive years of extensive orchard and semicommercial experimentations, the outstanding effectiveness of DDT for codling moth control had become well established in the Pacific Northwest. Its seasonal use, however, was expected to result in an "increase in population of several species of mites with consequent severe injury."

The following paragraphs are taken from the report of the 21st meeting, Western Cooperative Spray Project, held in Portland, January 22–23, 1947.

"The inclusion of an acaricide in all DDT applications appears warranted. No single program for mite control can be suggested, due to the various species of mites involved and the incomplete information relative to many materials being offered at this time. The application for mites must be especially thorough."

"The advantages of a DDT program may be nullified by failure to control mites. For successful mite control the program must be started early and continued throughout the period of mite activity. A successful program is dependent on prevention of an infestation. Control is difficult after a severe infestation develops."

In 1947 Washington apple growers went over to a DDT program and probably 90 per cent of the acreage in eastern Washington was sprayed with DDT to control worms. As expected, mites became abundant in midseason, and in August may orchards, particularly in the Yakima valley, showed russeted foliage due to heavy concentrations of mites. In previous

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years when light summer oils were added to lead arsenate or cryolite, the oil usually served to hold mites well in check.

Sulfur and rotenone insecticides are applied for mite control by many growers with variable results. A dinitro compound[1] has been used in quantity, generally with good results, although far more satisfactory for the Pacific mite than for the European red mite. Parathion, available in limited quantities and for experimental use only, gave the best control of all species of mites in 1947, according to investigations by W. J. O'Neill, Tree Fruit Experiment Station at Wenatchee.

CLOVER MITE, *Bryobia praetiosa* KOCH.—Known better as the brown mite in Western states, this species is more of a pest of soft fruits than of apples. Wintering over in the egg stage the brown mite has been observed early in the season on apple trees, but soon disappears, being replaced either by the European red mite or by the Pacific mite. The deep reddish eggs are abundant on occasion when deposited in large masses. Dormant applications of oil are relied upon to hold the brown mite in check.

While the brown mite is not generally considered important on apple trees in the Northwest it may become sufficiently abundant on peaches and cherries during the season to warrant special applications of acaricides.

PACIFIC MITE, *Tetranychus pacificus* MCGREGOR.—Recognized as a distinct species by McGregor in 1915, and described from Portland, Oregon, the Pacific mite has been rated as one of the most destructive crop pests in the Sacramento and San Joaquin valleys in California. Apricot, peach and prune trees have been defoliated in California, following a heavy infestation by this mite. In 1929 grape vineyards in the San Joaquin valley were heavily infested.

In the Wenatchee district the Pacific mite began to attract attention some time previous to 1930. At that time the pest was known locally as the two-spotted mite. While it was assumed that only one species was concerned, *i.e. Tetrancyhus bimaculatus*, the intensive web spinning habit was conspicuous. By 1932 the Pacific mite was causing severe damage to Delicious foliage in the experimental orchard at Wenatchee and was well established in the Wenatchee Valley.

The prevailing species in the Wenatchee Valley was generally considered as *Tetranychus bimaculatus* until 1937, although it was recognized that the habit of "cellophaning" over the calyx ends of apples was not characteristic of the common red spider. McGregor identified specimens as *T. pacificus* in 1937, and the species has been known in the Northwest since that time as the Pacific mite. It is now generally distributed over the irrigated fruit districts in eastern Washington.

Life History.—The Pacific mite winters over around the base of trees infested during the previous summer, covered with dead leaves, grass and debris. Late in March thousands of the orange mites may be observed in such locations, all of them females. A small proportion may spend the winter in the crotches of apple trees, even under rough bark of some of the larger branches.[2]

Winter mortality is high on occasion. Early in April, 1939, the mites were observed in moderate numbers around the base of trees heavily infested the previous season. Winter temperatures had been above normal and the upward movement on the trees had not been large. In this case the majority of the mites that went into hibernation in late summer failed to survive the winter. In other years, however, mites had been observed in tremendous numbers around the base of apple trees early in spring.

Upward movement of the mites begins in mid-March in an early season, continues during April, is completed by May 1. In 1939 50 per cent of the upward movement had been completed by April 11. This upward movement starts early where there is little or no cover crop, or only a sparse growth of weeds. In 1939 emergence reached a peak late in March under such conditions, and by April 7 95 per cent had moved upward to the unfolding leaves. Abundance of green grass close around the tree early in the year delays emergency by about a week.

With a lead arsenate or cryolite spray program on apples, in which summer oil

[1] *DN-111.*

[2] Most of our knowledge of the biology of the Pacific Mite is due to the careful and detailed observations of Dr. Irwin M. Newell, now a member of the teaching staff at the University of Oregon. These studies were begun in June, 1937 and continued throughout the next four seasons, *i.e.* through the summer of 1940. A detailed report of Dr. Newell's observations has never been published and I have drawn freely from his reports in the preparation of this paper.

was used, mite population built up on foliage at a slow rate during May and June. Early in June, 1939 at Wenatchee there was an average of only one mite per leaf in the Experimental orchard. Regardless of the slow start in 1939, mites increased rapidly during July and by mid-August counts of from 400 to 700 mites per leaf were not uncommon. Under the old spray programs it usually was not until July that the Pacific mite really became abundant. With a DDT spray program on apples, no oil is added and the mites build up earlier in the season accordingly.

At one time it was assumed that early applications of sulfur or lime-sulfur, applied during the period of upward migration, would materially check populations and aid greatly in control. James Marshall investigated this possibility one year at Wenatchee and found later in the season that trees sprayed during the upward movement of the mites were infested to about the same degree as other trees where no treatment had been applied. It was assumed in that event that the predacious mites had kept populations in the orchard at low levels.

Varietal Susceptibility.—For some reason Delicious trees are particularly susceptible to attack by the Pacific mite. In Wenatchee, in August 1939, there was an average of 995 mites and 1045 eggs per leaf on nine Delicious trees. On two Jonathans among these Delicious trees there was an average of 347 mites and 182 eggs per leaf; approximately one-third in intensity. In another count August 18, 1939, in an orchard adjoining the Experiment Station, there was an average of 253 mites and 87 eggs per leaf on Jonathans; 211 mites and 48 eggs per leaf on Staymans.

Generations.—According to observations in 1940 at Wenatchee, a maximum of 10 generations of the Pacific mite developed that year. This started with first generation females, progeny of overwintering forms, on May 8. The last generation occurred late in August, since eggs after September 1 were rare. According to Dr. Newell, peak populations of mature mites in August are not simply two or three overlapping generations, but really a composite of individuals which are 4, 5, 7 or even 10 generations removed from the initial stock.

One female Pacific mite will lay approximately 150 eggs during a period of 5 or 6 weeks in summer, according to observations at Wenatchee.

In 1940 the first significant movement downward of the orange forms was during the week of June 19–26. Actually these mites were only one, two or three generations removed from the maternal spring stock. The downward movement on this tree increased each week until a maximum was reached during the 9-day period July 18–26.

On a second tree the period of maximum descent was during the week of July 3–11. On a third tree, the downward movement did not start until the week of July 11–17 and did not reach peak until the second week of August.

TWO-SPOTTED SPIDER MITE, *Tetranychus bimaculatus* HARVEY.—Mites of this species have caused some injury to hops, particularly in Eastern Washington where approximately 10,000 acres are grown in the Yakima Valley. The total acreage in the State is about 12,000 acres.

In previous years control of spider mites on hops has been obtained by the use of a dinitro dust. Tetraethyl pyrophosphate, applied by fog machines, was used in many hop yards in 1947, with apparently satisfactory results.

Late July, 1946, B. J. Landis, Bureau of Entomology and Plant Quarantine, Yakima, showed me a potato field in lower Yakima Valley where this mite was present in large numbers. At first it was thought that the mites were secondary and the principal reason for injury in this field was due to late blight. This injury has been reported by Landis & Davis.

According to these authors a maximum of 71 mites per compound leaf was observed in a field of Netted Gem potatoes late in the season of that year, and "the death of numerous plants was attributed to the mite."

In every case infested fields has been dusted with one or more applications of DDT. Where mite damage was most severe potato fields had been dusted four or five times at intervals of 12 to 15 days. This adds another case of mite infestations that follow the use of DDT.

WILLAMETTE MITE, *Tetranychus Willamettei* McG.—Allied to the Pacific mite is another species that takes over in its place on tree fruits at Hood River in Oregon. While the Willamette mite is

much less common in Washington the species has been recognized in the state, and in 1946 was collected in the Wenatchee district (Squilchuck Canyon).

Mites of this species are more of a lemon color, as W. J. O'Neill and I saw them at Hood River early in September, 1947. These may have been the overwintering forms, however, comparable to the orange forms of the Pacific mite.

According to Leroy Childs the Willamette mite does not spin much of a web on foliage and may be easier to control on that account. While the Willamette mite is the dominant species at Hood River, it is in turn replaced by the Pacific mite at The Dalles, some 25 miles up the Columbia River where there is much less rainfall. It seems evident that the Willamette mite thrives best in a humid climate. Hood River has about 30 inches of rainfall a year.

The Willamette mite became a serious pest of raspberries in the Puyallup valley in 1947 according to observations by E. P. Breakey. The general use of DDT on raspberries may have been a contributing factor. At any rate the season ended with the largest mite populations on record. On the other hand, raspberry plantings in Snohomish county were severely infested with mites in 1947 where no DDT was used.

Mite populations begin to build up on the under sides of the lower leaves. As the season advances the mites move upward on the canes. By midsummer, injury to foliage may be severe. The injury appears as a drying or burning of the leaf, first around the margin; later the entire leaf withers and dries.

The use of dinitro compound[1] 4 to 8 ounces per 100 gallons of water, has resulted in very good control of the Willamette mite, according to Dr. Breakey. This was used with cryolite, applied primarily to control the orange tortrix. Tetraethyl pyrophosphate has also showed promise, particularly as a means of reducing the population of adult mites.

In general, the life history of the Willamette mite seems to be similar to that of the Pacific mite, although its life cycle has not yet been studied in detail.

EUROPEAN RED MITE *Paratetranychus pilosus* C. & F.—According to the literature, the European Red mite was first observed in the United States by Dr. H. E. Ewing in Oregon in the fall of 1911. At that time Ewing, was working at the Oregon Experiment Station at Corvallis. I feel quite certain, however, that I saw the egg of this mite in the spring of 1907 at St. Paul, Minnesota. At any rate, I brought in some mite eggs with little tufts on them which I supposed to be the eggs of the common red spider. Our experiment station artist made a drawing of these eggs with the tuft or stalk at the top but this was never used. It was not until 1918 that the European Red mite was first recognized as that species back in Pennsylvania.

While European Red mites are generally considered harder to kill than Pacific mites they reproduce at a lower rate. Newcomer & Yothers found that six complete generations of mites occurred in Yakima although there was a partial seventh and eight generations. From 15 to 18 days are required to complete the life cycle and only about 20 eggs were deposited by a single female.

Unlike the Pacific mite the European Red mite winters over in the egg stage on twigs and branches of the trees affected by the mites during the summer months. Oil sprays applied at winter concentration often zre recommended for the European Red mite and for scale at the same time. The scale has not been so much of a problem in recent years and many growers are likely to omit dormant or delayed dormant applications in years to come. It may be quite possible to do so, particularly if we find we can depend on some of the new insecticides to keep down two or three kinds of pests at the same time.

Seldom do we find the Pacific mite and the European Red mite on the same leaf or even on the same tree. Generally one species will predominate and the other will be conspicuous for its absence.

PEAR LEAF BLISTER MITE *Eriophyes pyri* (Pgst.).—Like the rust mite the blister mite overwinters beneath the bud scales and attacks unfolding leaves of apple and pear trees early in spring. The injury may be recognized by the presence of small greenish or reddish blisters which later become brown and dead. Reports of damage to foliage, caused by blister mites come in mostly from small orchards where dormant lime-sulfur sprays are

[1] DN-111.

seldom applied. Commercial orchards rarely show any evidence of damage. Occasionally trees grown without irrigation may suffer severe damage, even resulting in defoliation.

Becoming active early in spring, overwintering blister mites deposit hundreds of eggs in pear buds by the time these reach the cluster bud stage. Blister mite eggs of this first generation have been observed as early as March 20, in the White Salmon-Underwood district in Washington. In fact, some of these eggs were hatching March 22, 1941, an early season, according to observations by Newell and myself.

According to Newcomer and Rolfs, who made observations at Yakima some years ago, the early blisters are formed by the feeding of mites which hatch from eggs deposited in the unfolding buds by overwintering females. In other words, the first blisters are formed by the first generation mites rather than by overwintering mites.

In the Mount Adams orchard near White Salmon, Washington, a few blisters were found on pear foliage April 25, when the pears were one fourth inch in diameter or more. Mites, all stages and the eggs, were observed within the blisters. Openings in the blisters afforded ready access to the exterior. Apple trees were still in blossom at that time.

There is still some question as to whether blister mites attacking pear trees are the same as those feeding on apple foliage. Sometimes in the same orchard apple leaves may be severely attacked, pear foliage affected lightly, or the reverse. In California the destruction of pear buds during the winter months has been laid to what is termed the "bud form" of the blister mite. The habits and life history of these two forms vary to a marked degree. These bud mites feed activily and multiply under pear buds during the winter months in California. When pear trees come into blossom the mites feed on the developing fruit and cause these to be russeted and misshapen.

Apparently the bud form does not cause blisters on foliage. They feed and multiply on the growing tips during the spring and early summer but remain inactive in axils of leaves and in terminal buds in mid-summer. These bud mites become active again in August and September and work deeper under the bud scales.

According to *Ortho News* apples are more subject to injury by these bud mites in the Pacific Northwest than pears. Romes, Winesaps, Spitzenberg, Jonathan and Yellow Newtown varieties are affected. Approximately 20 per cent of the buds were killed in one orchard in August, 1932, according to this same authority.

Blister mites have been observed under Yellow Newtown bud scales, as many as 30 in a single bud, late in July at Wenatchee. This may have been the bud form since on the same date mites were seen inside blisters on pear foliage and many of these blisters were newly formed. Examination of pear buds at this time failed to reveal any blister mites.

Delicious buds examined September 10 were heavily infested by blister mites, a large number of which had penetrated to the center of the bud. At the same time a few mites were observed openly exposed on apples and pear leaves and within blisters on those leaves. Many newly formed blisters were in evidence on water sprouts of pear trees even this late in the season. Mites were common under bud scales of Bartletts at the time.

In the main fruit growing sections of eastern Washington, it is generally assumed that blister mites are held well in check by dormant applications of lime sulfur or oil made primarily to control scale. Again it is usually conceded that lime sulfur is more satisfactory than dormant oil. In the experiment orchard at Wenatchee during 1941 and 1942, with a light infestation of blister mites, pear trees sprayed with lime sulfur alone, or with the lime sulfur and oil combination at dilute concentrations, were much less affected with blister mites than trees sprayed with oil alone.

There is reason to believe that greater efficiency may be attained when applications of lime sulfur are held off until the delayed dormant, or even the cluster bud stage, when first generation mites are hatching in large numbers and are openly exposed on the unfolding leaves before many blisters are available as hiding places.

Some fruit growers are beginning to speculate as to whether dormant applications on apple and pear orchards may not become a thing of the past with the use newly developed organic insecticides,

some of which appear to be very effective in controlling mites. Investigations along this line are being undertaken at the Tree Fruit Experiment Station, under the direction of W. J. O'Neill. Unexpected angles may develop but it is not unreasonable to believe that in years to come dormant applications may actually be omitted and dependence placed on cover sprays for the control of mites, aphids, and even of scale.

THE BLACKBERRY MITE *Eriophyes essigi* HASAN.— First observed in Oregon and Washington in 1930, this species was studied by Arthur J. Hanson in Washington during 1931 and 1932, and by Edwards, Gray, Wilcox and Mote during the years 1931 to 1934. Previously this mite had been observed in California as early as 1921, although first identified as *Eriophyes gracilis*, later described as a new species by Hassan. The blackberry mite occurs all the way from the Mexican border as far north as Bellingham, Washington.

This mite feeds between the drupelets and the core of the berry, causing the development of a condition known as the "redberry disease of blackberries." Instead of ripening in the normal manner, affected berries assume a red color brighter than that of the unripened fruit, become hard in texture, and remain on the bushes until the old canes die during the winter. The "redberry" condition may vary from a single red drupelet in a blackberry to a single black drupelet in a red berry. According to Hanson the number of mites counted within a single red berry in late September varies all the way from less than 100 to as many as 683.

The most severe damage by the blackberry mite is on late maturing varieties, the Himalaya and Oregon evergreen. However, the mite has also been observed in cane buds of the Texas and Layton varieties, on Cuthbert raspberries and on loganberries.

Wintering over as adult mites under the bud scales on the axis of the bud and compound leaf, the blackberry mite begins to deposit eggs in late February and early March in western Washington. With this species the mite population does not reach a peak until late September. Predacious mites, particularly the species known as *Sejus pomi*, hold the blackberry mite in check during most of the season. These predacious mites have been found to winter over between bud scales where many blackberry mites are located.

Applications of lime-sulfur are recommended for the control of the blackberry mite. Lime-sulfur may be applied in October after the old canes have been removed, but the fall treatment should be followed by a second application in May with dilute lime-sulfur. If no treatment has been made in the fall, lime-sulfur may be applied late in March as a dormant treatment followed with dilute lime-sulfur in May. No sulfur sprays should be applied after May 20 on fruit intended for canning. Small quantities of sulfur in the cans may result in bursting of the cans due to the formation of sulfur dioxide.

LOGANBERRY MITE, *Phyllocoptes gracilis* (*Nal*).—This mite was first recognized as a pest of red raspberries in the Puyallup valley in 1944 according to E. P. Breakey. The following year loganberries were heavily infested, especially the immature fruits, turning brown and drying up early in the season.

Loganberry growers on Harstine Island have suffered heavy losses due to a condition known locally as the "dry berry disease," characterized by the dying and drying of the fruits soon after the petals have fallen. The earliest fruits are most seriously affected, the later fruits often escaping injury. Losses have often amounted to as much as 50 to 60 per cent of the crop. No causal organism has been associated with the disease and all evidence points to the mites as the direct cause of this "dry berry" condition.

CONTROL MEASURES.—Early applications of lime-sulfur as recommended for the blackberry mite, have reduced the damage to loganberry plantings on Harstine Island. Failure to apply lime-sulfur in good time, in March before the buds open, may result in considerable damage later in the season.

RUST MITE, *Vasates schlechtendali* Nal. *et al.*—The rust mite has been known to cause damage to apple and pear trees in the State for a number of years. Prunes and cherries are also affected.[1]

On West Coast the rust mite is generally distributed from British Columbia to California according to E. O. Essig, who

[1] According to H. H. Keifer the rust mite attacking cherry, plums and prune is *Vasates fockeni* Nal., while the rust mite of pear trees is *Epitrimerus pyri* Nal.

states that the mite becomes a pest only in the warmer and dryer sections in this area. Rust mites have been observed on apple and pear foliage in New York State, but the species is not recognized as an important pest in the Eastern United States. The rust mite has long been known in Europe.

Bartlett and Anjou pears often are severely russeted, especially around the calyx ends. On occasion this russeting may be followed by a scabbing over and cracking, resulting in a total loss. How much of this russetting is due to mite activity and how much may be due to frost will vary from year to year.

Occasionally cherry trees may be affected by rust mite although I have seen many cherry trees with foliage badly curled and yet was unable to find rust mites on the leaves. In that event the curled leaves probably were the result of insufficient water in mid-season.

On foliage the presence of mites is accompanied by a longitudinal rolling of the leaves upward, and a rusty brown color which may affect the entire tree. Hundreds of mites are often present on a single leaf. Rust mites appear to prefer the upper surface, although many are found on the lower side of the leaves. Tender apple leaves at terminals show the browning characteristic of mite injury beginning in June.

Severe injury to prunes, caused by the rust mite, occurred in 1929 in various orchard sections of the Pacific Northwest, particularly in the Milton-Freewater district of Oregon. In 1931, damage by the rust mite was reported from practically every fruit district in the Northwest. Heavy infestations were observed in the Milton-Freewater district of Oregon, at Dayton, in the Yakima valley, at Peshastin and in the Methow valley. In the last named area the omission of a dormant lime-sulfur spray in many orchards was generally blamed for the unusual abundance of the mites in 1931. Again in 1933 and 1938 rust mites appeared in abundance in Washington.

Cherries suffered some little injury during the summer of 1942. W. J. O'Neill called my attention to some Black Republican and Tartarian trees in an orchard near Cashmere in July, where the foliage was severely curled longitudinally, sometimes whole trees being affected. The Tartarian fruit failed to mature and became hard and shirveled.

Like the blister mite, rust mites spend the winter underneath the bud scales, beginning their activity about the time of the swelling of the buds early in April. In late summer rust mites move to their hibernating quarters underneath bud scales. Rust mites have been observed under scales of fruit buds as early as the last week in July at Wenatchee. A few were seen as late as September 10 at Wenatchee on apple and pear foliage.

While it is generally believed that dormant applications of lime-sulfur or the oil lime-sulfur combination are sufficient to hold rust mites in check, they may increase in numbers and gain the upper hand in mid-season. In 1941 a careful examination for rust mite was made in the Sid Thompson pear orchard near Bingen, Washington, by Irwin M. Newell and myself. That was early in spring following the dormant application of a dilute lime-sulfur to which three gallons of oil were added, far more than ordinarily recommended.

No rust mites were observed March 20, just before blossoms appeared, nor could any be found April 25. A third visit July 27, revealed the presence of rust mites in some numbers, though no special damage was observed. Apparently dormant applications are not sufficient to hold rust mites in check for the entire season.

Good control of rust mites has been obtained in previous years where summer oils have been combined with lead arsenate or cryolite in codling moth cover sprays. Apple trees sprayed with the oil-lead arsenate combination in the experimental orchard at Wenatchee in 1931 were practically free of rust mites in midsummer while adjacent trees where lead arsenate or fluorine compounds had been used without oil were moderately infested.

Classification, Food Plants, and Distribution of the Spider Mites

E. A. McGregor, *Whittier, California*

The subject of this paper is limited chiefly to the so-called spider mites or red spiders, which are in the Family Tetranychidae, Order Acarina. The region mainly concerned is the Pacific slope.

In the mites the body is not divided into a head, thorax, and abdomen as in the insects; these structures are fused, usually, into a somewhat oval-shaped body, often with an indistinct suture separating the anterior portion, called proterosoma or cephalothorax, from the posterior portion, called hysterosoma or abdomen. The former bears the first and second pairs of legs and the rostrum; the hysterosoma bears the third and fourth pairs of legs and the sex organs; the rostrum includes the mandibles, spina, and palpi. The anterior extension of the mandibles are needlelike stylets which are used for puncturing the plant tissue in feeding.

The spider mites are strictly phytophagus; most of them spin varying amounts of webbing over their colonies. The life histories of those species which have been observed, conform rather well to one pattern. The eggs are deposited singly on the surface of the plant; these hatch, during active seasons, in a few days, giving rise to the 6-legged larva; this is followed successively by the protonymph, the deutonymph, and the adult. The last three stages possess eight legs. Unfertilized females produce only male progeny.

Many species, under optimum conditions, complete a generation in from 10 to 12 days; there may be as many as 16 generations in a year. In the warmer regions spider mites may remain active and undergo development throughout the year, but in colder localities some type of hibernation takes place: The European red mite hibernates in the egg stage; most species of Tetrancyhus hibernate as adults. Some species show little preference between the host plants they feed upon, while others are more discriminating. Most species of spider mites thrive under relatively high temperatures and a minimum of rainfall, and the severest infestations occur normally during July and August.

Thirty to 40 species of natural enemies are known commonly to attack spider mites: A few of these are mites; the balance of them are insects. Probably the more effective of these predators are: The 6-spotted thrips, *Scholothrips sexmaculatus* Perg., the mite *Seiulus* sp., several minute itonid midges, the small coccinellid beetles, *Triphleps* spp., *Geocoris* spp., *Chrysopa* spp., and syrphid larvae. Collectively, the natural enemies seem to constitute an important factor in reducing populations of spider mites.

In the revision of 1919, by the present author (McGregor 1919) only seven genera were included in the family, as then treated; in the pending revision, 16 genera are recognized, of which four are new and previously undescribed. During the interval since 1919, the total number of known species of spider mites in the United States and Canada has increased from 27 to about 100, including new, unpublished species. Fifty species are now known to occur on the Pacific Coast; only five of these have been recorded from British Columbia.

Taxonomy.—Most of the structural characters used in the classification of the spider mites exhibit considerable variation within the family. This is true of the tarsal claw, the palpus, collar trachea, legs, body proportions, body hairs, and the male genitalia. When species are grouped into genera on the basis of a single morphological character, such a grouping does not necessarily remain logical for the other characters; it has been necessary, therefore, in the taxonomy of the spider mites, to select, in addition to other characters, one character for particular use in the separation of the genera and, for this purpose, the structure of the tarsal claw and its related appendages seem to be of most value. This claw is borne terminally on the onychium, the distal portion of the tarsus, and since certain variations occur between the claw of the male and the female, the claw of legs I of the female has been used in the classification. The structure of the aedeagus is

very useful for distinguishing the species. The differences in the structure of the terminal tarsal appendages of the tetranychid genera may be briefly described as follows:

Eutetranychus (=*Anychus*).—The claw is entirely lacking; 4 tenent hairs are borne on the onychium. (These tenent hairs persist in some form in all the genera.) In a new genus, allied with *Eutetranychus* the onychium is devoid of a claw, but it bears three pairs of tenent hairs. In the "boxwood mite," previously included in *Neotetranychus*, but actually a new genus, an inconspicuous, uncleft claw is present. In *Neotetranychus* the claw is split for a short distance apically into six spine-like or tusk-like spurs. In *Tetranychus* the claw is cleft to its middle or beyond into six subequal spines. In *Schizotetranychus* the claw is cleft nearly to its base into two widely diverging members; in some species each member bears two fine secondary spines. In *Septanychus* the main claw is cleft just as in *Tetranychus* but, in addition, a single straightish spur is borne dorsally, tangent to the claw's point of sharpest curvature. In *Paratetrancyhus* there is a single, uncleft claw which, near its base ventrally, bears from 6 to 10 spines which arise nearly from a common point. In *Tetranychina* the onychium bears a single uncleft claw, bearing along each side a comblike series of short tenent hairs. In *Petrobia* the onychium bears a single uncleft claw, which bears on each side a small series of short tenent hairs: This arrangement resembles that of *Tetranychina*, but other structures in *Petrobia* readily separate it from *Tetranychina*. In *Bryobia* two uncleft claws arise from the onychium, each bearing a pair of long tenent hairs; a median pulvillus, between the claws, also bears two tenent hairs. In a new genus the claw arrangement resembles that of *Bryobia*; the pair of long tenent hairs are borne more distally on the claws than in he latter genus; other characters readily separate these two genera. In *Neophyllobius* two strong uncleft claws, devoid of hairs, are borne on the onychium; a median pulvillus bears a double series of short tenent hairs. In *Tuckerella* the onychium bears two stout, uncleft claws, each bearing along its base pectinate series of tenent hairs; between the claws a median pulvillus bears paired series of tenent hairs. In *Monoceronychus* the tarsus is devoid of true claws, but in their place are borne two bladelike structures, each bearing a pair of tenent hairs; between these blades arises a pulvillus which bears a double series of tenent hairs. A new genus has its onychium furnished with two bladelike structures, each bearing on one edge a pectinate series of short tenent hairs; an apical pulvillus bears a double series of tenent hairs.

Distribution and Economic Importance.—The folowing discussion concerns chiefly the distribution and economic importance of the spider mites of the Pacific coast. It may be noted that California appears to contain the largest tetranychid fauna. This may be misleading, due to the fact that the present author has collected widely in that area. Certain mites not yet reported in other regions, may subsequently be found to occur there.

A new genus of mites, allied with *Eutetranychus*, occurs in southern California on native plants in the family Malvaceae.

The boxwood mite, known as *Neotetranychus buxi* Garman, occurs in northern and southern California on species of *Buxus*.

In the genus *Tetranychus*, 27 species are known to occur on continental North America, 10 of which are undescribed; 17 of these occur on the Pacific coast, inincluding British Columbia.

The 2-spotted mite, *Tetranychus bimaculatus* Harvey is perhaps the most widely distributed spider mite in the United States and Canada. It occurs throughout the Pacific coast. It has been recorded from a great number of food plants, mostly non-woody plants, but is found at times on orchard trees. The 2-spotted mite is of much economic importance.

Tetranychus atlanticus McG. occurs in northern and southern California, and in ten other states. It has been recorded in California from cotton, clover, alfalfa, strawberry, lima bean, walnut, violet, and sunflower. *T. atlanticus* is not known to occur north of California on the Pacific slope.

Tetranychus willamettei McG. occurs in British Columbia, Washington, Oregon, and California. It has been recorded from apple, pear, grape, raspberry, maple, willow, oak, and sevreal woody shurbs. It is a serious pest, especially in Oregon on

apples and pears, and in central California on grapes and other fruits.

Tetranychus pacificus McG. is probably the worst spider mite pest in the hot central valleys of California. It occurs throughout the Pacific coast, including British Columbia, and also in Idaho, Utah, and Colorado. It attacks deciduous fruit trees, especially in interior California and eastern Washington; in addition it has been recorded on grape, fig, Chinaberry, *Citrus*, walnut, cotton, and 15 other food plants. The Pacific mite often has to be combatted on ornamental trees, as well as on agricultural crops.

Tetranychus sexmaculatus Riley (6-spotted mite) is an important pest of *Citrus* in Florida and California. Its distribution in California is limited mostly to southern California, where it is combatted at times. It also occurs on avocado, carob, sycamore, maple, and a few other plants.

Tetranychus yumensis McG. and *T. lewisi* McG. occur on *Citrus* in southern California.

Tetranychus libocedri McG. damages the incense cedar in the high Sierras. (It was collected by airplane at a great altitude over Texas.)

Tetranychus californicus McG. occurs in central and southern California on poplar.

Two new species of *Tetranychus* occur in California, one on guayule, and one on a native species of *Malvastrum*.

In the genus *Schizotetranychus*, nine species four of which are undescribed, are known to occur in North America; two species occur in Florida, two species in Connecticut, and five species occur in California. No species are known to occur on the Pacific coast north of California. Five of the known species of *Schizotetranychus* attack grasses and related plants, as is true with all but one of the California species.

The genus *Septanychus* contains six known North American species. A new species occurs in Ontario, Canada, on apples; *S. tumidus* (Banks) is a serious pest on numerous plants in Florida; two new species occur in California one of which attacks the royal palm; one occurs on cotton from Texas to Arizona; one species occurs in Mexico. No species of *Septanychus* is known to occur on the Pacific coast north of California.

The genus *Paratetranychus* contains 23 species known to occur in North America; six of these are undescribed. Of these, 13 species occur in California, 3 in Arizona, 3 in Washington, 2 in Oregon, 2 in Canada, 2 in Utah, 1 in Nevada, and 1 in Wyoming. In addition to *P. pilosus* (C. & F.), the only species of *Paratetranychus* known to occur in Canada is *P. americanus* (Ewing). Species in this genus are rather hardy mites often with stout dorsal bristles. Most of them have eggs with a dorsal stalk.

Perhaps the most important species of *Paratetranychus* are the six following: *P. pilosus* (C. & F.), the European red mite, is generally distributed throughout the United States and Canada, and in Europe. It attacks deciduous fruit trees, and 13 other food plants, mostly in the family Rosaceae. Control measures are widely used against this mite.

P. citri (McG.), the citrus mite, occurs in Florida, Georgia, South Carolina, Louisiana, Alabama, Mississippi, and California. It attacks all varieties of *Citrus*, and 9 other food plants. This is the worst spider mite pest in southern California, and is combatted extensively. In May, 1948, its occurrence in central California was established for the first time.

P. simplex (Banks), the date mite, occurs in California, Arizona, Texas, Florida Utah, and Nevada. It attacks palms and grasses, and is frequently combatted in the Coachella Valley, California, on dates.

A new species, the sycamore mite, occurs throughout California. It is a serious pest of sycamore trees, and also attacks English walnut, camphor, *Eucalyptus*, spp., and seven other plants.

P. ununguis (Jacobi), the spruce mite, occurs in Europe, in six eastern states, and California. It attacks spruce, oak, English walnut, and maple.

P. viridis (Banks), the pecan mite, attacks pecan in Texas and S. Carolina.

P. coiti (McG.), the avocado mite, occurs in southern California on avocado, and rarely on a few other plants. It is combatted on avodaco.

P. alpinus (McG.) occurs in Washington, Oregon, and California. It attacks incense cedar and other conifers.

P. stickneyi (McG.) occurs throughout California on grasses.

P. peruvianus (McG.) occurs in Peru on willow, and in southern California on carob.

P. pratensis (Banks) has been reported only from eastern Washington on timothy grass.

Four additional new species of *Paratetranychus* occur in California: One attacks the ponderosa pine in northern California, and occurs on other pines in Arizona and Virginia; one injures the Monterey pine from San Francisco to southern California; one recently was found on valley oak, near Berkeley, by A. E. Pritchard; a fourth undescribed species of Paratetranychus attacks grasses in southern California.

The genus *Tetranychina* is represented by four known species, three of which occur mainly in the southeastern and southern states. The Pacific coast is represented only by a single new species of *Tetranychina*, which attacks the seaside lupine in California.

Petrobia is a monotypical genus, containing a single species, *P. latens* (Muller). This is a cosmopolitan species, occurring in Europe, the United States, and elsewhere. On the Pacific slope, *P. latens* is known from Washington, Oregon, California, Arizona, Utah, and Idaho. From Kansas southward, it commonly attacks grains, which at times are severely damaged. It has been reported from a few other crop plants.

Bryobia praetiosa Koch, the almond or clover mite, appears to be the only valid species in the genus. It is cosmopolitan and occurs throughout the United States and Canada. The clover mite attacks desiduous fruit trees, almond, English walnut, and numerous other plants. It frequently has to be combatted. With approaching winter, this mite often enters houses for shelter.

The genus *Neophyllobius* contains six known species, five of which are undescribed: Three species occur in the southern states; three occur in California. One is found on live oak in southern California; one on fig in central California; one in the high Sierra on incense cedar. Little is known of the habits of these mites.

The genus *Tuckerella* contains one known species, recorded from Hawaii, Australia, and South Africa. It was once intercepted at the port of Los Angeles. *Tuckerella* is a very grotesque mite.

The genus *Monoceronychus* contains a single species, *M. californicus* McG., which occurs in central and southern California on grasses.

A new genus of spider mite, possibly allied with *Monoceronychus*, occurs in southern California on Bermuda grass.

In addition to the tetranychid mites, numerous other mites occur on crop and other plants on the Pacific coast. Among those known to be phytophagus are two serious eriophyid pests, the rust mite, (*Phyllocoptruta oleivorus* (Ashm.) and the bud mite, *Eriophyes sheldoni* Ewing; the genus *Tenuipalpus*, as heretofore conceived, is represented in California by *T. californicus* (Banks) and two new species; two additional plant-feeding mites are *Tarsonemus bakeri* Ewing and a beetle-mite, *Eremaeus* sp. The seven last named mites all attack *Citrus* in California. Two mites, previously placed in the family Tetranychidae and in the genus *Caligonus*, are *C. terminalis* Qualye and *C. mali* Ewing; *C. terminalis* occurs on Citrus in southern California. *C. mali* occurs on fruit trees in British Columbia, Idaho, Washington, and Oregon.

Several predaceous mites occur commonly on the Pacific slope, the more common of which are: *Seiulus* sp., *Anystis agilis* Banks, *Scirus longirostris* Herm., and *Cheletogenes ornatus* (C. & F.)

It is obvious that there is great need of a revision of the spider mites, currently bringing together in a single publication, all of the known species in the group. This would seem to be especially true, considering the fact that the use of some of the newly developed insecticides has resulted in a heavy build-up of spider mite populations in many regions of the United States, thus bringing these mites into greater prominence. Such a manuscript was prepared some time ago, and it is hoped that it may be published and available to workers in the not too distant future.—3-8-48.

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Development of the Two-Spotted Spider Mite in the Presence of DDT and Other Insecticides[1]

CURTIS W. WINGO and GEORGE W. THOMAS, *University of Missouri, Columbia*

With the development of DDT the codling moth has assumed an almost secondary role as a pest in pear and apple orchards. Most commercial orchardists now assume that the codling moth will be controlled if a well timed and thoroughly applied DDT program is used. On the other hand, the orchard mites, particularly the common red spider or two spotted spider mite *Tetranychus bimaculatus* Harvey and the European red mite *Paratetranychus pilosus* (C. & F.) have developed into pests of prime importance in orchards sprayed with DDT.

This increase in mites is attributed by most entomologists to the reduction of predators in the orchard by the DDT sprays applied for codling moth control. Steiner *et al.* (1944) first reported increased numbers of both the European red mite and the two spotted mites on small experimental orchard plots which had been sprayed with DDT. They also reported the lady beetle, *Stethorus punctum* (Lec.) to be absent from DDT sprayed plots, while in adjoining unsprayed trees they were present in large numbers. From that first year until the present time the use of DDT in orchards has almost invariably produced a mite problem of considerable magnitude.

It is now rather widely accepted that this increase of mite populations in orchards is due entirely to the destruction of mite predators by DDT. Early users of DDT often said that the DDT stimulated the mites inferring that some chemical stimulus was afforded the mites by the DDT. One still hears this inference occasionally.

As early as 1943 Weigel (1944) found an apparent kill of 13 per cent in 48 hours of two spotted mites on beans sprayed with 4 pounds of 5 per cent DDT per 100 gallons of water. Subsequent investigations by Romney *et al.* (1945) showed that a DDT-acetone-sulfonated vegetable oil emulsion (0.3 per cent DDT) was effective against the two spotted mite on Guayule. Later Romney (1947) reported that DDT emulsions (DDT 0.3, solvent 0.6, white oil 0.3 and emulsifier 0.001 per cent) gave high kills of both mites and eggs.

The experiments reported below were designed to determine the influence of various concentrations of DDT on the development of the two spotted spider mite in the absence of predators. The influence of other insecticides and acaricides upon two spotted mite development is also reported.

In a preliminary experiment, single soybean plants, variety Ralsoy, growing in 6-inch clay pots were used. Five plants were sprayed with each concentration. As a check five plants were sprayed with tap water. As soon as the plants were dry they were infested by gluing to each a blade of wheat bearing 10 eggs of the two spotted spider mite. The edges of all pots were coated with petroleum jelly to prevent infestation from without. The pots were placed at random in a moist sand bench in the greenhouse. Thirteen days later the plants were resprayed just as at the start of the experiment except that to each concentration and to the check 0.3 gram of spreader[2] per liter was added to overcome wetting difficulties experienced at the first spraying. Fourteen days later each plant was dismembered and the live and dead stages were counted under the binocular microscope. Results of the experiment are shown in table 1.

Table 1.—Development of the two-spotted mite on DDT sprayed soybeans. Initial infestation 10 eggs per plant.

Treatment	Eggs Hatched per Plant Average	Live Stages per Plant After 27 Days	
		Mites	Eggs
DDT 0.5%	7.4	5.2	20.6
DDT 0.25%	9.0	23.6	44.4
Check	8.6	291.6	1079.8

Considerable variation was introduced by unequal initial infestation as indicated by the egg hatch shown in table 1. However, both 0.5 per cent DDT and 0.25 per cent DDT significantly reduced two

[1] Missouri College of Agriculture Journal Series No. 1123.

[2] Monsanto Chemical Co. (*Santomerse "D"*).

spotted mite build up during the 27 day period involved.

Shortly after the above trials were run, another set of plants was started. The techniques and materials differed only in that Arksoy variety of soybeans was used and the plants were infested with three adult two-spotted spider mite females as soon as the first spray had dried. The plants were resprayed 11 days after infestation and checked for live stages 18 days after the second spray. Table 2 shows the increase in mite populations 29 days after the initial infestation.

Table 2.—Development of the two-spotted spider mite on DDT sprayed soybeans. Initial infestation 3 adult females per plant.

TREATMENT	LIVE STAGES PER PLANT AFTER 29 DAYS	
	Mites	Eggs
DDT 0.5%	117	216
DDT 0.25%	722	911
Check	824	1982

The procedures and techniques in the next tests were modified considerably in order to overcome several objectionable features noted in the first trials. The total length of time involved in the test was shortened and the concentrations of DDT were both increased and decreased. Each treatment was replicated four times and the pots randomized as to position in a 4 by 4 latin square in the sand bench. The plants were first sprayed when two true leaves had developed and each plant was infested with 3 adult females as soon as the leaves were dry. Seven days later the plants were resprayed. Twelve days after the second spray the plants were dismembered and live and dead of all stages recorded. Results of these counts are found in table 3.

Table 3.—Development of the two-spotted spider mite on DDT sprayed soybeans. Initial infestation three adult females.

TREATMENT	LIVE STAGES PER PLANT AFTER 19 DAYS	
	Mites	Eggs
DDT 1.00%	0.00	3.0
DDT 0.75%	0.25	0.5
DDT 0.125%	50.00	191.0
Check	201.00	841.0

The bean plants sprayed with high concentrations of DDT were stunted and had several leaves severely burned. Those plants sprayed with 1.00 per cent DDT averaged only 4.5 inches in height compared to 6.87 inches for the check plants which were sprayed with tap water and wetting agent. Slight stunting and chlorosis was noted on plants sprayed with lower concentrations of DDT.

Following the same procedure used in the preceding tests a series of plants sprayed with .009 per cent parathion, .125 per cent chlordan and .125 per cent DDT were infested with 3 adult females and allowed to run through the same period of time (19 days) with respraying taking place 7 days after initial infestation. Final counts of live stages 19 days after infestation appear in table 4.

Table 4.—Development of the two-spotted spider mite on soybeans in the presence of parathion, chlordan and DDT. Initial infestation three adult females.

TREATMENT	LIVE STAGES PER PLANT AFTER 19 DAYS	
	Mites	Eggs
Parathion .009%	00.25	00.25
Chlordan .125	77.20	360.00
DDT .125	21.50	109.70
Check	105.20	345.00

The reduced numbers of both eggs and mites on the DDT sprayed and check plants in this experiment as compared to the one preceding was caused largely by position in the greenhouse. The former were in dry sunny benches while the latter were in shady, damp benches.

The final experiment contained eleven materials which have either been used in orchards for red spider control, proposed for such use or are sometimes used in regular apple spray programs to control insect pests. These materials, sources and recommended concentrations are listed below:

DDT—a 50 per cent wettable powder. Generally used at 2 pounds per 100 gallons for codling moth control.

Methoxychlor,[1] a wettable powder containing 50 per cent Bis (methoxy phenyl) trichlorethane. Used for codling moth control.

Chlordan—a wettable powder containing 50 per cent technical chlordane equivalent to 30 per cent

[1] Dow Chemical Co.

Octochloro-4,7-methano-Tetrahydroindane and 20 per cent related compounds.

Benzene hexachloride[2]—a 50 per cent wettable powder containing 6 per cent of the gamma isomer of hexachlorocyclohexane and 44 per cent of the other isomers of the same. It is often used to control grasshoppers in orchards at 4 lbs. per 100 gallons.

Chlorinated Camphene,[3] a wettable powder containing 25 per cent of technical chlorinated camphene (chlorine content 67–69 per cent). Recommended for grasshopper control in orchards at the rate of 2 lbs. of technical chlorinated camphene per acre.

Parathion[4]—a wettable powder containing 25 per cent of an aryl alkyl thiophosphate, a new and very promising acaricide.

Xanthone[5]—a wettable powder containing not less than 71.5 per cent of Xanthone. Recommended at the rate of 1.25 lbs. per 100 gallons for summer control of orchard mites.

DDT Emulsion[6]—an emulsifiable DDT solution containing 25 per cent technical grade DDT, 72 per cent of a mixture of alkyl napthyl ethers and 3 per cent emulsifying agent. Recommended at a dilution of 1 to 800 for codling moth and red mite control in orchards.

Fungicide[7]—An experimental insecticide-fungicide of the dinitro type compounded as a 25 per cent emulsion and suggested for mite control at the rate of 1 quart per 100 gallons. Also compounded as a 25 per cent wettable powder and suggested for mite control at the rate of 2 lbs. per 100 gallons. A wettable powder containing 40 per cent of bis (p-chlorophenoxy) methane,[8] and suggested for mite control at the rate of 2.25 pounds per 100 gallons.

In general the techniques followed closely those outlined in the last two experiments. Each material was replicated four times. The sprayed plants were ininfested with 3 adult females and two adult males as soon as the plants were dry. Pot positions in the sand bench were random. Seven days after initial infestation the plants were resprayed. Thirteen days after the second spray the plants were dismembered and live and dead stages were recorded. The average numbers of live mites and eggs per plant for each treatment is found in table 5.

Both formulations of the fungicide injured the soybeans severely. The emulsion form caused severe burn, crumpled and deformed leaves on all plants treated. The wettable powder caused the same injury to a lesser degree.

[2] E. I. Dupont & Co.
[3] Hercules Powder Co.
[4] American Cyanimid Co.
[5] General Chemical Co.
[6] U. S. Rubber Co.
[7] Dow Chemical Co.
[8] Rohm & Haas Co.

Table 5. Development of the two spotted spider mites on soybeans sprayed with various insecticides and acaricides. Initial infestation 3 ♀ and 2 ♂.

Treatment 2 Sprays		Live Stages per Plant After 21 Days	
		Mites	Eggs
DDT-Wettable Powder	.125%	231	502
DDT-Emulsion	.125	186	874
Methoxychlor	.125	56	311
Benzene hexachloride	.125	269	752
Chlorinated camphene	.125	48	296
Chlordan	.125	174	489
Xanthone	.111	646	2464
Fungicide Wettable Powder	0.77	31	29
Fungicide Emulsion	.062	26	66
bis(p-chlorophenoxy) methane	.125	12	58
Parathion	.009	7	41
Check		342	980

High temperatures in the greenhouse caused the protective vasoline barriers on the pots to break down and even though they were repaired daily there was some indication of infestation from without. This served to intensify somewhat the rapid increase of mite populations in the presence of some materials.

Discussion and Conclusions.—Soybean plants treated with various concentrations of DDT were infested with the two spotted spider mite in order to determine the ability of the mites to increase on DDT sprayed plants in the absence of all insect and mite predators. Orchard strength DDT sprays (.125 per cent) were found to inhibit mite development to the extent that only 40 to 60 per cent of a normal population (populations normally developed on check plants sprayed with water) developed on soybean plants sprayed with this concentration. When the concentration was increased to .25 per cent DDT there was no significant decrease in mite and egg populations on the sprayed plants. However, when the concentration of DDT was increased to 0.5 per cent only 8 per cent of the normally developing populations developed. At even higher concentrations 0.75 per cent and 1 per cent DDT, less than 1 per cent of the normal number of live stages were present. A 0.125 per cent emulsion of DDT and a .125 per cent concentration of chlordane sprayed on soy-

bean foliage kept the mite populations down to about the same level as those developing on foliage sprayed with .125 per cent DDT wettable powder.

Methoxychlor (0.125 per cent) and chlorinated camphene (.125 per cent) allowed only 25 per cent of a normal population of mites and eggs to develop.

Three of the materials used as wettable powders inhibited mite and egg development to such a degree that less than 5 per cent of a normal population developed on foliage sprayed with parathion (.009 per cent), bis (*p*-chlorophenoxy) methane (.125 per cent) and the dinitro fungicide (.077 per cent). Of the three abovementioned, Parathion sprayed soybeans showed the lowest populations of mites and eggs at the end of the tests.

The extremely high numbers of both mites and eggs occurring on the xanthone treated beans cannot be explained at this time. Field tests at Campbell, Mo. in 1947 which included xanthone as an acaricide for the European red mite showed that xanthone sprayed apple trees had populations of the two spotted spider mite developing even though the check trees (sprayed with .125 per cent DDT alone) showed none of this species present.

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Studies of Orchard Acaricides

E. J. NEWCOMER and F. P. DEAN, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The general use of DDT for controlling the codling moth, *Carpocapsa pomonella* (L.), on apple trees in the Pacific Northwest resulted in a marked increase in the infestation of orchard mites (Newcomer & Dean 1946). Control measures that had been successful when used with lead arsenate or cryolite were no longer effective, and it became necessary to find better acaricides.

In 1947 tests were made against the European red mite, *Paratetranychus pilosus* (C. & F.), and the Pacific mite, *Tetranychus pacificus* McG., in separate orchards. Acaricides were either added to the DDT used for controlling the codling moth or were used alone. It was planned to put on as many applications of each material as needed to effect good control of the mites, rather than to compare the materials on the basis of an equal number of applications. By means of a mite-brushing machine,[1] counts of live mites and eggs were made at intervals during the season. The ideal way would be to make a count just before each application and others at intervals thereafter. This was not always possible, but enough counts were made to give an excellent indication of the control that was being obtained.

Figures 1, 2, and 3 show the infestation graphically in terms of number of live mites per leaf. In order to keep the charts as simple as possible, the number of eggs is not shown, although the data on eggs were used in determining when to spray. The spray applications are indicated on

[1] Made available through the courtesy of R. W. Burrell, Bureau of Entomology and Plant Quarantine.

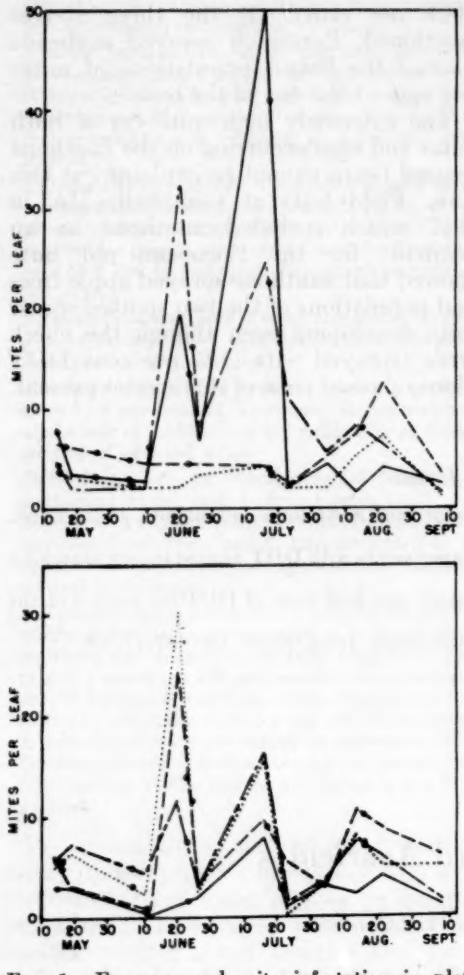

FIG. 1.—European red mite infestation in plots sprayed with various acaricides, mostly in combination with DDT. (Upper Graph: Solid line, Cryolite; parathion; Long dashes: Xanthone, 1 lb., 5 applications; Short dashes: Xanthone, 1 lb., 3 applications; Long and short dashes; Dinitro compound; Benzene hexachloride. Large dots indicate spray applications. Lower Graph:—Solid line, Benzene hexachloride; parathion; Long dashes, Tetraethyl pyrophosphate; Short dashes, Rotenone; Long and short dashes, Mineral Oil; Large dots, indicate spray applications.

the charts by dots. Each plot included in figures 1 and 2 consisted of eight trees, located at random about the orchard, and 10 representative leaves from each tree were used in making the counts.

Figure 1 shows the infestations of the European red mite resulting from the use of various acaricides. The first count was made on May 14, before any spray had been applied, and showed an average infestation of about 5 adult mites and 90 eggs per leaf.

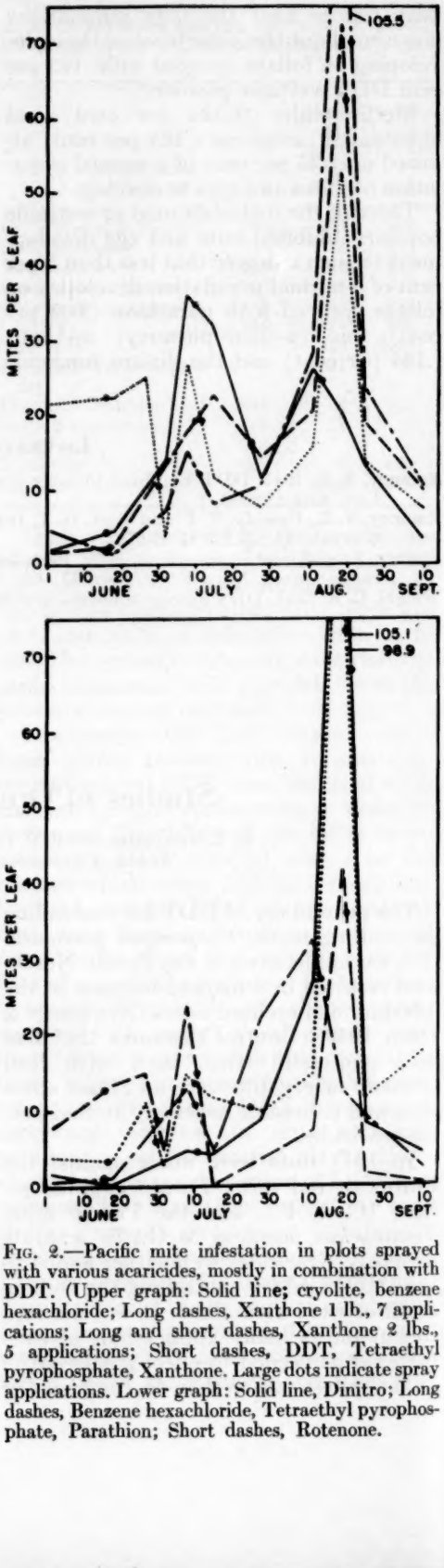

FIG. 2.—Pacific mite infestation in plots sprayed with various acaricides, mostly in combination with DDT. (Upper graph: Solid line; cryolite, benzene hexachloride; Long dashes, Xanthone 1 lb., 7 applications; Long and short dashes, Xanthone 2 lbs., 5 applications; Short dashes, DDT, Tetraethyl pyrophosphate, Xanthone. Large dots indicate spray applications. Lower graph: Solid line, Dinitro; Long dashes, Benzene hexachloride, Tetraethyl pyrophosphate, Parathion; Short dashes, Rotenone.

In plot 1 a standard treatment of 3 pounds of cryolite and 1 quart of oil to 100 gallons of spray was used for controlling the codling moth. Because three applications of DDT were used on the rest of the orchard, the first at 1 pound and the others at 0.5 pound per 100 gallons, mites became very numerous in plot 1. One-half pound of a wettable powder containing 15 per cent of parathion was added to the spray applied on July 17, and no further trouble with mites was experienced.

Three applications of technical xanthone at 2 pounds with DDT in plot 3 kept the mites at a low level throughout the season, and five applications at 1 pound of xanthone in plot 2 was almost as good.

The dicyclohexylamine salt of dinitro-*o*-cyclohexyl phenol controlled the mites well in plot 4 during the early part of the season, being used at 1 pound with DDT (1 pound) but later, when the quantity was reduced to 0.5 pound, control was poor. It is not considered safe to use more than 0.5 pound in the Pacific Northwest during the hot part of the summer.

In plot 5 benzene hexachloride (6 per cent gamma isomer) in the form of a wettable powder was used at 3 pounds per 100 gallons in the first spray for controlling the woolly apple aphid, *Eriosoma lanigerum* (Hausm.), followed by two applications of technical tetraethyl pyrophosphate (tetraethyl phosphate 9 per cent, other organic phosphates 16 per cent) at 0.5 pint and one of 15 per cent parathion at 0.25 pound.

In plot 6 five applications of the tetraethyl pyrophosphate at 0.5 pint were made, and control in the two plots was roughly parallel. (No count was made in plot 5 on June 20; therefore no peak of infestation at that time is shown on the chart.)

One pint of a commercial product reported to contain 1 per cent of rotenone in plot 7, and 2 quarts of mineral oil in plot 8 gave roughly parallel control except that the peak on June 20 was lower where the oil was used. Neither material controlled the mites so well as did xanthone.

Figure 2 shows the infestations of the Pacific mite resulting from the use of the same acaricides that were used against the European red mite. Because of uneven distribution of mites in the trees, the first counts were delayed until June 2, by which time two cover sprays had been applied.

Cryolite 3 pounds, and oil 1 quart per 100 gallons (with benzene hexachloride, 2 pounds, 6 per cent gamma, added to three of the applications to control the woolly apple aphid) permitted a fairly heavy infestation of mites to persist throughout the season. Xanthone did not control the Pacific mite so well as it did the European red mite, and control was much the same with seven applications at 1 pound in plot 2 as with five applications at 2 pounds in plot 3, both used with DDT.

In plot 9 the methoxy analog of DDT was used in place of DDT, and a fairly heavy infestation had built up by the end of June. An application of 0.5 pint of tetraethyl pyrophosphate at that time, followed by one of 2 pounds of xanthone on July 14, kept the mites fairly well controlled for the rest of the season.

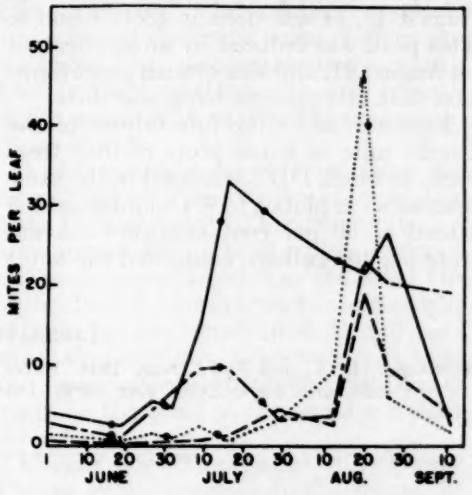

FIG. 3.—Pacific mite infestation in plots sprayed with various chlorinated hydrocarbons in combination with DDT. (Solid line, Chlordan; Broken line, DMC or 1,1-bis (*p*-chlorophenyl) ethanol; Short dashes, Dichloro-phenoxy methane; Long and short dashes, Chlorinated camphene; Large dots, spray applications.

In plots 4 to 7 three or four applications of DDT were used for controlling the codling moth, the first at 1 pound and the others at 0.5 pound per 100 gallons. It is evident that the addition of the salt of dinitro-*o*-cyclohexyl phenol in plot 4 resulted in better control of the Pacific mite than of the European red mite in the other orchard. In this orchard it was used

at 1 pound in the first three applications, followed by two applications at 0.33 pound. In plot 5 benzene hexachloride was added in the first three applications for controlling the woolly apple aphid. On June 30 tetraethyl pyrophosphate was used at 0.5 pint, which reduced the infestation only temporarily. On July 14, 0.5 pound of 15 per cent parathion was used, which reduced the mites to zero. A month later the infestation in plot 5 was up to about 40 mites and 40 eggs per leaf, and a second application of parathion, this time at 0.25 pound, again reduced the infestation to a very low level.

Five applications of tetraethyl pyrophosphate at 0.5 pint to 100 gallons controlled the mites very well in plot 6, but seven applications of rotenone at 1 pint were required in plot 7 for similar control. The very high peak of infestation in plots 2, 3, 4, and 7 on August 20 could have been prevented by spraying those plots on August 13, as was done in plots 1 and 6. This peak was reduced by an application on August 21, and was of such short duration that no apparent harm was done.

Figure 3 shows the infestations of the Pacific mite in small plots of four trees each, in which DDT was used in the same manner as in plots 4 to 7. Chlordan, at 0.5 pound of 50 per cent emulsion concentrate per 100 gallons, controlled the mites well in plot 12 until the end of June, but after that, although the trees were sprayed seven times altogether, control was poor. The proportion of red color on the apples was unusually high, but the apples were rather small. One and one-half pints of a 25 per cent emulsible 1,1-bis(*p*-chlorophenyl)ethanol, used in plot 13 on May 7 and 29 and June 17, gave such outstanding control of the mites that no further spraying was necessary. Two pounds of 40 per cent 1,1-bis(chlorophenoxy)methane gave excellent results in plot 14, although five applications at this rate were used. Five applications of a 50 per cent water-miscible chlorinated camphene at 1 pint in plot 15 also controlled the mites very well. Two pounds of a fused bentonite-sulfur were tried in plot 11, which is not shown in figure 3, but seven applications were needed for fair control. None of these materials caused any injury except the 1,1-bis(*p*-chlorophenoxy)methane, which produced small russeted spots on about half of the apples.

Of the acaricides tried in 1947, 1,1-bis(*p*-chlorophenyl)ethanol and parathion are the only ones that show promise of being effective when used with DDT in a practicable number of sprays. It is possible that not over three applications of either of these materials per season would be needed because of their residual action.

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DDT Dust for Control of Onion Thrips

J. WILCOX and A. F. HOWLAND, U.S.D.A., *Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

During the summer of 1943 Smith (1944) increased the yield of table onions by spraying them with DDT for the control of the onion thrips, *Thrips tabaci* Lind. Smith *et al.* (1945) obtained similar results with DDT aerosols. Chapman *et al.* (1945) showed that 5 and 10 per cent DDT dusts were toxic to the onion thrips on onions. Peay & Sorenson (1946) increased the yield of onion seed by controlling this insect with 10 per cent DDT dust.

In experiments during 1944 the authors obtained better control of the onion thrips on bulb onions with DDT than with a number of other insecticides, including nicotine and tartar emetic. Of the several DDT preparations used, the 10 per cent dust mixture was the most promising. In 1945, therefore, a 3-year experiment on the timing and the number of applications

of 10 per cent DDT dust to table onions for thrips control was begun at the Alhambra, Calif., laboratory of the Bureau of Entomology and Plant Quarantine.

PROCEDURE.—The experiment involved 9 treatments tested in randomized blocks. Each year from 1945 to 1947 there were 8 replicates in each of 3 fields, or 9 fields for the 3 years. Seven of the fields were located in the Coachella Valley and two in the San Gabriel Valley of southern California. In the Coachella Valley the onions are seeded in September or October and transplanted in December, when they are about 6 inches high. Most of the subsequent growth takes place from February to April, during which time the thrips populations build up and control measures are applied. The onions are harvested in the latter part of April or the first of May. In the San Gabriel Valley the onions are transplanted from January to March and harvested in June and July. Most of the fields were planted in 2-row beds 24 to 36 inches from center to center. The plots were 25 to 50 feet long and 5 to 9 beds wide.

Table 1.—Schedules for treatments with 10 per cent DDT dust in nine onion fields, 1945–47, approximate dosage 30 pounds of dust per application.

TREATMENT	WEEKS IN WHICH APPLICATIONS WERE MADE	POUNDS APPLIED PER ACRE
1	First, second, and third	92
2	Fourth, fifth, and sixth	90
3	Seventh, eighth, and ninth	90
4	First six	181
5	Fourth to ninth, inclusive	181
6	First, third, fifth, seventh, and ninth	150
7	First, third, and fifth	90
8	Fourth, sixth, and eighth	91
9	Check (no treatment)	

A dust mixture containing 10 per cent of technical DDT was used in all the tests. In 1945 and 1946 the DDT was diluted with only pyrophyllite, but in the 1947 season 25 per cent of sulfur was included. Applications were made with a rotary hand duster at the rate of 30 pounds per acre over a 9-week period beginning when the onions were about 10 inches high. In 1945 two trips were made with the duster for each bed, that is, one for each row. In the other two seasons only one trip was made per bed per application. There was no difference in thrips control between the the two methods of application.

The experimental treatments differed only in the time, and amount of applications, as shown in table 1.

Thrips counts were made in the fields on 4 plants per plot at four times during the season, as follows: Before treatment began, on the the same day or one day previous to making the first application; end of first three weeks, one week following the third application and previous to the fourth application; end of second 3 weeks, one week following the sixth application and previous to the seventh application; end of third 3 weeks, one week following the ninth application. In other other words, thrips counts were made for each 3-week period either on the same day or 1 day previous to the insecticide application (a pre-application count) and 1 week following a series of three applications (a post-application count). Counts made at the fourth and seventh weeks served both as pre- and post-application counts.

Yield records were obtained from the central 20 feet of one or more of the middle beds in each plot. This constituted a minimum of 100 bulbs in a plot. The tops and roots were clipped from the bulbs, the bulbs cleaned, and the number and weight of bulbs per plot determined. As no plants were killed outright, yields were computed and comparisons between treatments made on the basis of the average weight per onion.

EFFECT OF TREATMENT ON ONION THRIPS POPULATIONS.—In the control of larvae 10 per cent DDT dust applied at 30 pounds per acre per application was found to give excellent control, based on counts made one week after a series of applications was terminated. The results obtained at various intervals throughout the season are shown in table 2.

In most cases reduction in larval populations was 90 per cent or higher. Where applications were terminated at the end of the third week (Treatment 1) or at the end ofthe sixth week (Treatment 2), the larval populations built back up to the original numbers in a 3-week period and exceeded the original populations in a 6-

week period. This population build-up after the termination of a series of applications is illustrated in figure 1. For example, three applications of Treatment 1 were made at weekly intervals during the first 3-week period, and the larval population was reduced from 16 larvae per plant at the start of the experiment to one per plant at the fourth week; at the seventh week the population had increased to 22, and at the tenth week to 120 per plant. In

Table 2.—Number of thrips per plant and per cent reduction at various periods during the dusting season. (Averages of 9 fields, 1945–1947.)

Treatment[1]	Larvae		Adults	
	Number Per Plant	Per Cent Reduction	Number Per Plant	Per Cent Reduction
	Before treatment began			
9	16	—	4	—
	End of first 3 weeks			
1	1	97	4	67
4	1	97	4	67
6	2	93	4	67
7	3	90	4	67
9	30	—	12	—
	End of second 3 weeks			
1	24	66	29	19
2	2	97	10	72
4	1	99	12	67
5	1	99	8	78
6	11	84	20	44
7	9	87	22	39
8	5	93	16	56
9	70	—	36	—
	End of third 3 weeks			
1	121	15	32	0
2	123	14	28	12
3	18	87	15	53
4	92	36	25	22
5	8	94	11	66
6	32	78	12	62
7	117	18	26	19
8	37	74	23	28
9	143	—	32	—

[1] See table 1 for treatment schedules.

several fields at the beginning of the tenth week, plots receiving Treatment 1 had a higher larval population than had the untreated plots. These plants were still in a thrifty growing condition and attractive to the thrips, whereas the untreated plants were drying up because of thrips damage and were unattractive to the thrips.

With treatment 4 there was an average of one larva per plant for the first six weeks, but on the termination of treatment the thrips built up to 92 per plant in the last three-week period. Before Treatment 5 was begun, the population had built up to 30 larvae per plant; it was reduced to one per plant at the end of the sixth week, and to 8 per plant at the end of the ninth week. Applications made at 2-week intervals (Treatments 6, 7, and 8) did not give such outstanding control as did the applications at weekly intervals, but nevertheless held the populations to comparatively low levels during the treatment period.

Any residual action on thrips larvae that the DDT dust might have had was either dissipated before counts were made or obscured by the new growth of the onion plants, on which thrips could feed without exposure to the insecticide. As the onions grow about 2 inches a week and produce on an average two new leaves every three weeks, large areas at the base of the plants are uncovered on which there are no insecticidal residues.

Control of the adult thrips was not nearly so good as it was for the larvae, averaging less than 70 per cent for counts made one week after the termination of a series of applications (table 2). Since the adult is motile, it migrates into the fields from other crops and may redistribute itself within a week's time over a given field from the untreated areas contained therein. The experimental design leaves a considerable portion of the fields untreated for each 3-week period—five-ninths for the first and third periods, and one-third for the second. Undoubtedly better control of adults would be demonstrated if the counts were made sooner than a week after treatment. However, it was not economically possible to do this, as these experimental fields were located more than 100 miles from the laboratory.

As the adult populations are less stable than the larval populations, the following discussion is limited to larval populations only.

RELATION OF THRIPS POPULATIONS TO CROP YIELD.—Increased yields from the dust applications were apparent in six of the nine fields treated. These benefits were not always significant in individual fields, largely because of the great varia-

Table 3.—Comparison of larval thrips populations on undusted onions in fields where no damage occurred and in fields where damage occurred.

FIELD[1]	VARIETY	YEAR	AVERAGE NUMBER OF LARVAE PER PLANT[2] Before First Treatment	End of 1st 3 Weeks	End of 2nd 3 Weeks	End of 3rd 3 Weeks
		Fields in which no damage occurred				
(2)	Early Spanish	1945	14	17	36	67
(4)	Early Texas Grano	1946	2	13	30	137
(6)	Yellow Bermuda	1946	3	1	28	170
	Average		6	10	31	125
Mean temperature, fields (4) and (6)				62.3°	61.8°	71.5°
		Fields in which damage occurred				
(1)	Crystal White Wax	1945	35	51	44	62
(3)	Late Spanish	1945	54	59	136	69
	Average		44	55	90	66
(5)	Crystal White Wax	1946	8	44	85	63
(7)	Early Texas Grano	1947	6	24	133	345
(8)	Crystal White Wax	1947	6	18	57	298
(9)	Crystal White Wax	1947	13	45	76	77
	Average		8	33	88	196
Mean temperature, fields (5), (7), (8), and (9)				63.6°	65.6°	73.6°

[1] Fields 2 and 3 were in the San Gabriel Valley and the remainder were in the Coachella Valley.
[2] Counts made at end of period and before the dust applications.

tion in the soils and in the soil fertility within the fields, especially in the Coachella Valley. The fields that were damaged and those that were undamaged by thrips are reported separately in table 3.

These differences in population build-up appear to be related to temperature. Temperatures in the damaged fields as compared with those in the undamaged fields show an average mean temperature 1.3° F. higher for the first 3-week period, 3.8° higher for the second 3-week period, and 2.0° higher for the third 3-week period.

In the fields in the Coachella Valley (Fields 1, 4, 5, 6, 7, 8, and 9) treatments were begun in February, and the high population at the beginning of treatment in Field 1 cannot be accounted for by mean temperatures. Mean temperatures in the Coachella Valley during January averaged 54.7° F. in 1945, 54.5° in 1946, and 53.6° in 1947. Frost records appear to indicate the reason for the early build-up

Table 4.—Average weight per onion bulb, in pounds, in treated fields.

TREATMENT	1945 Field (1)	1945 Field (2)	1945 Field (3)	1946 Field (4)	1946 Field (5)	1946 Field (6)	1947 Field (7)	1947 Field (8)	1947 Field (9)	AVERAGE
1	0.226	0.632	0.239	0.220	0.216	0.252	0.299	0.219	0.198	0.278
2	.226	.645	.226	.222	.192	.225	.316	.236	.202	.276
3	.205	.615	.199	.229	.188	.200	.287	.218	.204	.260
4	.231	.624	.295	.223	.225	.238	.368	.231	.237	.296
5	.215	.615	.235	.215	.214	.212	.352	.252	.236	.282
6	.238	.650	.246	.229	.204	.236	.317	.242	.244	.289
7	.244	.635	.254	.212	.214	.227	.362	.240	.249	.292
8	.202	.622	.224	.232	.202	.226	.326	.262	.255	.283
9	.218	.610	.172	.208	.187	.241	.261	.197	.182	.253
Difference required for significance at odds of 19 to 1:	.025	[2]	.032	[2]	.020	.026	.054	[2]	[2]	.016

[1] There were eight replicate plots in each field except No. 7, from which one replicate was omitted because of an unsatisfactory stand of plants.
[2] No significant difference by F test.

in 1945 compared to the build-up in other years. In 1945 frost occurred on 2 days in January and 2 days in February. In 1946 frost occurred on 4 days in January and 5 days in February. In 1947 there were 7 days with frost in January and none in February. The frosts in February 1946 probably also contributed to the slow build-up of populations that year and lack of damage in two of the three fields. In Field 1 the slight increase in population between the fourth and seventh weeks was attributed to a late frost during the first week in April.

It will be noted that in all fields where no damage occurred there was a marked increase in population between the seventh and tenth weeks due to high temperatures. In several of the fields where damage occurred, there was a reduction in population between the seventh and tenth weeks (Fields 3 and 5 in table 3). This reduction was due to thrips damage, which caused the plants to dry up and become so unattractive that the thrips deserted them. This tremendous increase in larvae per plant and the very rapid decline were well illustrated in Field 9 by an increase from 157 to 579 larvae per plant between the end of the seventh and eight weeks, and a decrease to 77 larvae per plant within the following week.

In the undamaged fields the populations averaged 8.3 larvae to a plant during the first 3-week period, 20.7 to a plant during the second 3-week period, and 77.8 to a plant during the third 3-week period. In the damaged fields with similar starting populations the larval populations averaged 20.5 to a plant for the first 3-week period, 60.5 to a plant for the second 3-week period, and 141.8 to a plant during the third 3-week period. As there is no significant benefit in crop yield from control applications during the third 3-week period (Treatment 3 in table 4), most of the damage therefore occurs during the first 6 weeks. More damage is done to small plants by low populations than to larger plants by high populations. In the first 3 weeks, with an average of 20.5 larvae to a plant, the plants ranged from 10 to 16 inches in height, and in the second 3 weeks with an average of 60.5 larvae to a plant, the plants ranged from 16 to 21 inches in height. In the third 3 weeks, with an average of 141.5 larvae per plant and the plants 21 or more inches in height, there was no significant benefit from treatment.

TIMING OF APPLICATIONS IN RELATION TO CROP BENEFITS.—In table 3 the fields in which damage occurred and in which benefit from treatment was apparent are separated into two groups, one in which there was an average of 44.5 larvae per plant at the start of treatment (Fields 1 and 3) and the other one in which there was an average of 8.1 larvae per plant at the start of treatment (Fields 5, 7, 8, and 9). When the yields (table 4) from these fields are averaged, there is only a slight increase in favor of beginning treatment when the larval population is low.

As several varieties of onions are included in these averages, a comparison of fields of the same variety seems more equitable. When the fields of the Crystal White Wax variety are compared (Fields 1, 5, 8, and 9) the fields which averaged 8.7 larvae per plant at the beginning of treatment had an increase in bulb weight to nearly twice that for the field which originally averaged 35.0 larvae per plant. These comparisons involve onions that were about the same size at the beginning of treatment, *i.e.*, about 10 inches high and with 4 leaves. Undoubtedly more benefit from treatment would have been obtained if the treatments had been begun when the onions were smaller and the thrips populations lower.

Other comparisons between the time of beginning treatment can be obtained from the yield records for all fields which are shown in table 4. These comparisons, however, are not based on the same size onions as are discussed above. For example, Treatment 1 was begun the first week, when the onions were 9.66 inches high with 4.4 leaves (1947 averages), Treatment 2 was begun the fourth week, when the onions were 16.41 inches high with 5.95 leaves; and Treatment 3 was begun the seventh week, when the onions were 21.98 inches high with 7.58 leaves. Table 2 shows an average of 16 larvae per plant the first week, 30 at the fourth week, and 70 at the seventh week. The yield records show no significant differences between Treatments 1 and 2, but these treatments are significantly better than Treatment 3, which shows no significant differences in comparison with the untreated plots. The data indicate that yields were not affected by a 3-week delay in beginning treatments, during which

time the larval population increased from 16 to 30 larvae per plant and the height of the onions increased from 10 to 16 inches. Yields were decreased, however when treatments were delayed an additional 3-weeks, during which time the population increased to 70 larvae per plant and the height of the onions increased to 22 inches.

Better comparisons of the time of beginning applications can be obtained by restricting the comparisons to the fields of Crystal White Wax onions and to the treatments which extend the control over a longer period of time. Treatments 4 and 7, beginning the first week, and Treatments 5 and 8, beginning the fourth week, all extend over 6-week periods. These comparisons show an increased yield in favor of the treatments begun the first week, but the difference is not significant with 64 replicate plots. In these fields there were 15.4 larvae per plant at the first week and 39.5 larvae per plant at the fourth week. These data indicate, but do not prove, that more benefit from control applications can be expected if the applications are begun when the onions are 10 inches high and have an average of 16 larvae per plant than can be expected from applications begun when the onions are 16 inches high and have an average of 39 larvae per plant.

ECONOMIC FACTORS RELATING TO CONTROL AND TO A CONTROL PROGRAM.—In table 4 all treatments except No. 3 show a significant increase in yield over the untreated plots. Three applications at weekly intervals (Treatments 1, 2, and 3) for any of the 3-week periods do not give outstanding results, because the treatments do not cover a long enough period. Control operations apparently must extend over a 6-week period, as the best results were obtained with Treatment 4 (6 applications at weekly intervals beginning the first week) and with Treatment 7 (3 applications at 2-week intervals beginning the first week). Treatments 4 and 7 were not statistically better than treatments 5, 6, and 8 but were more profitable.

Table 5 shows the yields, the cost of treatment, and the net gain or loss for each treatment calculated at three price levels after the cost of treatment and error have been deducted. When all the fields are considered, the most profitable treat-

Table 5.—Yields, cost of treatment, and monetary gains at several price levels on bulb onions dusted with 10 per cent DDT.

TREATMENT NO.[1]	YIELD PER ACRE, IN 50-POUND SACKS	GAIN COMPARED TO CHECK, IN 50-POUND SACKS	TREATMENT COST[2]	NET GAIN OR LOSS AFTER ALLOWANCES ARE MADE FOR ERROR[3] AND TREATMENT COST, WITH SACKS OF ONIONS SELLING AT—		
				$1.00	$2.00	$3.00
			Nine fields, all varieties (1945–47, 71 replicate plots)			
1	630	56	$16.20	$ 2.80	$21.80	$ 40.80
2	627	53	16.20	− 0.20	15.80	31.80
3	591	17	16.20	−36.20	−43.80	−76.20
4	671	97	32.40	27.60	87.60	147.60
5	640	66	32.40	− 6.60	25.60	54.60
6	656	82	27.00	18.00	63.00	108.00
7	663	89	16.20	35.80	87.80	139.80
8	642	68	16.20	14.80	45.80	76.80
9	574	—	—	—	—	—
			Four fields, Crystal White Wax variety (1945–47, 32 replicate plots)			
1	570	49	16.20	6.80	29.80	52.80
2	569	48	16.20	5.80	27.80	49.80
3	542	21	16.20	−21.20	−26.20	−31.20
4	614	93	32.40	34.60	101.60	168.60
5	609	88	32.40	29.60	91.60	153.60
6	616	95	27.00	35.00	108.40	180.00
7	629	108	16.20	65.80	147.80	229.80
8	612	91	16.20	48.80	113.80	178.80
9	521	—	—	—	—	—

[1] For treatment schedules, see table 1.
[2] At 14¢ per pound for insecticide and 4¢ per pound for labor of application.
[3] Differences between yield per acre required for significance at odds of 19 to 1, 37 sacks for all varieties; 26 for the Crystal White Wax Variety.

ment with onions selling at one dollar per 50-pound sack is Treatment 7 (three applications at 2-week intervals beginning the first week), and the second best is Treatment 4 (six applications at weekly intervals beginning the first week). With onions at two dollars per sack, Treatments 7 and 4 are still outstanding, but are practically equal. With onions at three dollars per sack, Treatment 4 is better than Treatment 7, but only at this price level does it justify the extra cost as compared with Treatment 7.

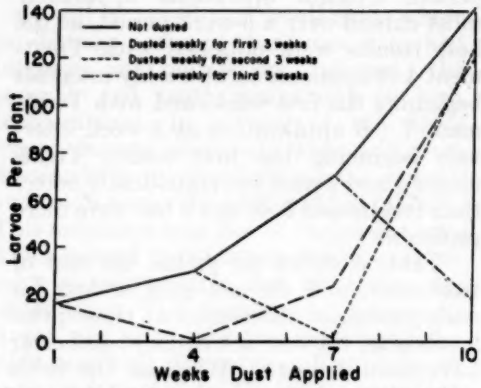

FIG. 1.—Onion thrips larvae on onions as affected by applications of 10 per cent DDT dust during different 3-week periods.

When only the Crystal White Wax fields are considered, Treatment 7 is outstanding and the most profitable treatment at all price levels. In this variety three applications at weekly intervals (Treatments 1 and 2) are significantly inferior to three applications at 2-week intervals (Treatments 7 and 8). Additional applications do not seem to be justified.

SUMMARY.—In an experiment conducted in southern California for the control of the onion thrips, *Thrips tabaci* Lind., 10 per cent DDT dust was used at 30 pounds per acre-application in several treatment schedules. The treatment schedules covered a 9-week period beginning when the onions were 10 inches high, and applications were made at weekly and 2-week intervals. Three fields were treated each year, 1945 to 1947, inclusive, and the nine treatments were replicated eight times in each field.

Control of larvae averaged about 92 per cent and of adults about 64 per cent in those counts made one week after the termination of a series of treatments. After the termination of the treatments for the first and second 3-week periods, the populations built up in a week's time to a point equalling or exceeding the original populations. This ineffectiveness of the DDT residues was thought to be due to rapid plant growth. Benefits in increased crop yields were obtained from the treatments in six of the nien fields.

The main differences between the damaged and undamaged fields was due to population build-up during the first 6-week period and was associated with temperature. Frost records also appeared to influence the population levels, especially at the beginning of the season. An average of 8.5, 20.7, and 77.8 larvae per undusted plant during the three 3-week periods, respectively, caused no measurable damage, while populations of 20.5, 60.5, and 141.8 larvae per plant during the same periods caused damage. Most damage occurred during the first 6 weeks when the onions were smaller and the populations lower than in the last 3 weeks. With onions 10 inches high and populations between 8.5 and 35.0 larvae per plant, more benefit is indicated from treatment begun when populations are smaller. Treatments begun when the onions are 10 inches high appear to be better than treatments begun when they are 16 inches high and applications begun either time are significantly more effective than applications begun when the onions are 22 inches high. When the cost of treatment and the error are considered, treatments beginning when the onions are 10 inches high and covering a 6-week period, either as three applications at 2-week intervals or six applications at weekly intervals, are the most profitable.

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Grain and Grass-Infesting Thrips

STANLEY F. BAILEY, *University of California, Davis*

In North America little attention has been paid by entomologists to grain and grass-infesting thrips. For a number of years we have been gathering notes on this group of pests and our attention was recently focused on a severe infestation of fescue range grass at Davis, California by *Chirothrips aculeatus* Bagn. This local problem stimulated a review of the overall picture of this group of pests.

In Europe a great deal has been written concerning thrips as pests of grains, particularly in the Scandinavian countries and north and central Europe. Some of the principal European workers on this group of insects are cited in the references at the conclusion of this paper.

Thrips injury to grains and grasses in Europe is known as "silver-top," "bad-head," or "white-ear." These terms are encountered rarely in North American literature. The typical appearance of thrips-injured plant tissue is that in which the growing points are shrivelled, malformed or blasted, and the white, streaked or blotched areas (from which the chlorophyll has been removed) on the leaf blades are in sharp contrast to the normal tissue. Such injury has been illustrated frequently in the European publications, particularly those of Hukkinen. Osborn (1888, 1891) was one of the first North American entomologists to recognize this type of insect injury. Both adults and larvae feed together in the protected portions of the leaf sheaths and flower parts and are seen less often on the exterior portions.

In Europe, wheat, oats, rye, barley, millet, flax, and various pasture grasses are attacked and damaged to varying degrees annually by a number of different thrips species, some of which occur in North America. Such estimates of injury as those of Stranak (1912) point out a loss of from 25 to 100 per cent of rye in Bohemia. The Russian workers Rubtzov (1935), Pavlov (1936), and Grivanov (1939) have shown that each thrips reduced the weight of a grain by 1 mg. Grains attacked by five or more thrips caused 10 times as much loss in weight as grains attacked by one individual thrips. An average as low as one-half thrips per grain reduced the weight of wheat by about 5 per cent. The species involved in these studies was chiefly *Haplothrips tritici* Kurd. Hukkinen (1936) found that *Chirothrips hamatus* Tryb. injured meadow foxtail grass, *Alopecurus pratensis* L., to the extent of 25 per cent in 1932 and 3 per cent in 1934. In 1933 Sharga stated that records of *Limothrips cerealium* Hal. injuring grains date back to the middle of the 18th century. In 1805 losses were severe and in some areas in England one-third of the crop was lost. Sharga's investigations showed 17 per cent of florets of wheat damaged and 38 per cent of spiketlets on oats. Linnaniemi (1935) observed considerable reduction in the grass seed crop from *Aptinothrips rufus* Gmel. and injury to clover by *H. niger* (Osb.).

Injury to flax by *Thrips lini* Lad. is severe in several European countries especially Holland, France, and Germany. Doeksen (1938), Morison (1943) and others have published on this problem.

In other parts of the world other thrips namely, *Haplothrips oryzae* (Mats.), is very injurious to wheat and rice in Japan (Murata & Sekiya, 1927), *Thrips oryzae* Wms. is a pest of rice in India (Ayyar 1932), and *Haplothrips cerealis* Pr., (Priesner, 1940) injures wheat in Syria. Bianchi (1945) reported *Anaphothrips obscurus* Müller causing damage to Sudan grass and sugar cane in Hawaii.

Among the published reports on injury in North America are those of Seamans (1928) who describes a loss of 10 per cent to oats in Canada by *Limothrips cerealium* Hal. Garman (1892) also reported severe injury to oats in Kentucky by this thrips. R. C. Smith (1943) lists this species as a pest of grain in Kansas. Hewitt (1914) in a study of *Anaphothrips obscurus* on oat varieties concluded that the later blooming types such as "Banner" sustained as high as 36 per cent sterility from thrips feeding. This study and earlier records in Alberta and British Columbia show injury to this grain crop to the extent of 50 per cent. Hinds (1900) wrote that "The damage from *Anaphothrips obscurus* (in Massachusetts) appears to be most severe to worn-out meadows, fields and lawn"; the per cent of injured heads as high as 95

on *Festuca*. Cary (1902) found this thrips to be a serious pest of various grasses in Maine and Cooley (1902) described similar injury to cereals in Montana. Kelly (1915) described in detail the injury caused by *Prosopothrips cognatus* Hood to wheat in Kansas and adjoining states.

In Idaho and Ontario red clover and alfalfa seed suffer loss from *Haplothrips niger* (Osb.). Since Burrill (1918) and Ross (1918) reported this type of injury no further notes in the literature have been seen or studies made of this thrips in North America. Osborn (1939) reviewed his earlier observations on this species and cited the other authors mentioned.

A brief summary of the life history of the species known to be injurious to grains and grasses follows. The five species discussed below are found in the old world only.

Stenothrips graminum Uzel. The eggs are laid in the flowers of wild oats and barley, each female laying about 100. Kolobova (1926) found the egg stage to be 7 days in the laboratory. The larval stage extends for 7 to 10 days. Pupation takes place in the soil and the resting stage lasts 6 to 6.5 days at depths of from 6 to 20 inches. The winter is passed in the adult stage in the soil at depths to 31 inches. There appears to be only one generation a year in Russia. Morison (1943) states there are probably two generations a year in southern England and that hibernation occurs in the larval stage.

Chirothrips hamatus Tryb. All stages are found in the ears of grasses and the adults emerging in the fall remain in the dead hosts until the following spring. Hukkinen (1936) reported considerable additional detail in his studies of this species.

Thrips lini Lad. The flax thrips has only one generation a year. According to Doeksen (1938), the newly-emerged adults leave the soil in mid-May and migrate to flax, feeding and ovipositing in the top leaves. Four weeks usually completes the development from egg to mature larva. The winter season is passed as a larva.

Haplothrips aculeatus F. In northern Europe and Russia two summer generations which over-lap considerably, occur on wheat. The eggs are laid on the ears (the females lacking an ovipositor). The larval stage consumes 10 to 14 days and the pupal stage 6 to 8 days. Körting (1930, 1933) found that the larvae developed faster on the rye flowers than on the grains. The winter is passed by the adults under fallen leaves and in grass.

Haplothrips tritici Kurd. The larvae hibernate in soil at a depth of 4 to 4.5 inches in Russia (Grivanov 1939). Larvae and pupae are found in stubble in the fall in Sicily (Del Giudice 1935) and the winter season is passed as both pupae and adults.

Many additional species are recorded from grasses and grain in Europe but they are of minor importance; von Oettingen (1942) lists, for example, 92 species found in grasslands in Germany.

The rice thrips. There are three species of thrips known to attack rice, *Thrips oryzae* Wms. in India, *Haplothrips oryzae* (Mats.), and *H. japonica* (Mats.) in Japan. The Indian species is particularly injurious in dry years. All stages are found on the plants although pupation also occurs in the soil. *H. oryzae* is reported to have two generations a year, the adults appearing near the end of June and again in August. All stages are found throughout the summer. The adults pass the winter in sheltered places.

The following seven species are known as pests in Europe and North America. *Anaphothrips obscurus* and *Limothrips cerealium* have the greatest distribution.

Grass thrips, *Anaphothrips obscurus* (Müller). The eggs are laid in the normal manner in new leaf tissue. This stage varies from 4 to 15 days. Females lay 50 to 60 eggs each. The larval stage is also 4 to 15 days long. The pupae transform in 4 or 5 days or less in among old leaf sheaths near or on the ground. There are eight or nine generations a year. The length of life cycle varies from 30 days in spring to 12 days in summer. Only adult females hibernate and these are nearly all of the brachypterous form. They are found in among the dead grass and at the base of the plants during the winter. In California adults are found throughout the year. As the wild hosts dry up the macropterous forms are produced which disperse on many hosts during the summer. Hinds (1902), Morison (1943), and von Oettingen (1942) have reported many detailed facts on this species.

Anaphothrips secticornis Tryb. This species, also known as *A. apteris* (Dan.), is found in the same environment with *Anaphothrips reticulatus* Moult. Independent colonies are often present in the

same locality but mixed populations are rare. It injures wild oats and ripgut grass as does its relative but its distribution does not extend as far eastward from the coast to the edge of the interior valleys of California as *reticulatus*. Its life history is similar to its relative with the exception of the lack of winged forms.

Grain thrips, *Limothrips cerealium* Hal. The females hibernate usually in trash, under bark, in dead grass, and even in buildings. Miles (1921), however, reported finding the larvae through the winter in hollow-stemmed grasses. There are two to three generations a season and a seasonal peak is reached at harvest time. The eggs are laid in tender leaf and flower tissues. Pupae are found in leaf-sheaths and flower parts. The egg stage lasts 10 to 13 days, the larval stage 13 to 17 days, the pupal stage 8 to 10 days and the total life cycle 30 to 35 days.

It has been only in recent years that this species has become abundant in northern California where it is very common on wild oats, *Avena fatua* L. The writer first found this species in 1932 in Southern California. The early collections of Jones, Moulton, and others did not report this thrips from the west coast. The various European workers cited in this paper especially Van Eecke (1922), Jablonowski (1936) and von Oettingen (1942) have all discussed this species.

Limothrips angulicornis Jablon. This species has a life cycle and seasonal history similar to *cerealium* but rarely becomes sufficiently abundant in the western states at least, to be of any concern in contrast to *cerealium*. The preferred host appears to be fox-tail, *Hordeum murinum* L. on which it reaches a seasonal peak as the heads mature.

Limothrips denticornis Hal. This grain thrips also has a life history similar to *L. cerealium* and all stages are found in the ears of barley and rye. Ion (1931) found the females only hibernating. Towards the end of May the eggs are laid in the heads of rye and the larva appears in about a week. In Europe it is reported (von Oettingen 1936) to be more abundant in wet seasons. It is very rare in North America but is recorded from wheat (Herrick 1924) in New York.

Chirothrips aculeatus Bagn. This thrips, rather uncommon in Europe, frequently breeds up in very large numbers in California in late winter and early spring. Its principal host is foxtail grass, *Hordeum murinum* L. We have taken this thrips from other incidental hosts such as tomato, pear, fig, and various weeds, but aside from its chief host, it is numerous on wild oats, barley and wheat. In the spring of 1947 an extremely heavy population was evident in the Sacramento Valley area. During this period it completely destroyed the seed of fescue increase plots of the Agronomy Division, University of California, at Davis. During the late fall and winter adult females may be found under bark of trees and among dry grass and weeds. Reproduction begins in late winter on the wild hosts and reaches a peak at the time the foxtail matures. Flights of the females are common and late grain and seed crops in the vicinity of pastures and uncultivated areas become infested. In late summer and fall the adults distribute themselves widely and go into semi-hibernation. The habit of feeding in the heads of grasses and grains is similar to that of *Limothrips*. Priesner (1926, p. 142) has described the larval stage and Andre (1939) the male.

Aptinothrips rufus Gmel. This wingless thrips is found throughout the year on various grasses and commonly on grains in small numbers. The egg stage is 18–20 days, the larval stage 14 days, the pupal stage 8 days, and the whole life cycle 40 days. It is many-brooded and the generations overlap. All stages are found throughout the year but the larvae reach a seasonal peak in May in permanent pastures, lawns, and uncultivated areas. It is of no concern in commercial grain fields. It is often swept up in such large numbers on an insect net that it is practically impossible to count accurately. It has a wide distribution in North America and we have collected it up to 7500 feet elevation in mountain meadows. Normal cultivation practices keep the population down to a minimum and its wingless condition precludes seasonal migrations.

The remaining species are found only in North America.

Anaphothrips reticulatus Moulton. This west coast species is wingless and feeds entirely on grasses. It is found the year around, particularly on ripgut grass, *Bromus rigidus* Roth, which it often damages severely. Wild oats frequently growing in association with the grass like-

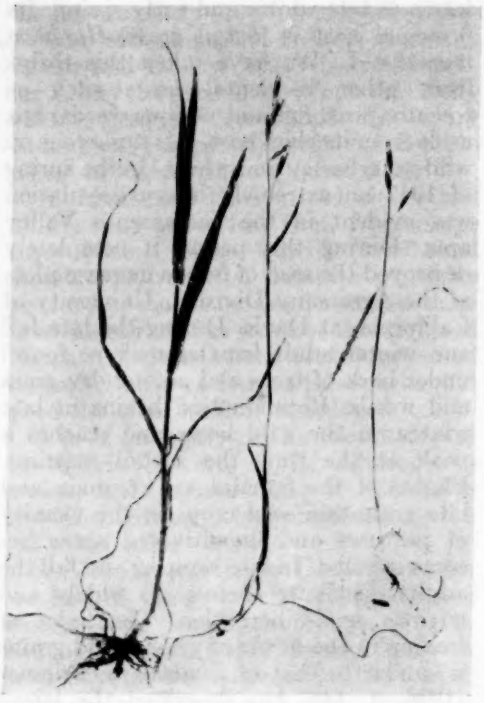

FIG. 1.—Injury to wild oats by *Anaphothrips reticulatus* Moulton.

wise is injured (Fig. 1). In seasons of prolonged rains it breeds up in very great numbers which results in very little seed production of the hosts and a stunting of the plants. Adults and larvae feed on the surface of the leaves and in the sheath. Pupation occurs at the base of the plants in debris. The larval stage is often prolonged in cold weather but lasts 10 to 15 days in May. The pupal stages extend over a period of 4 to 5 days at this time. During the hot, dry summer and early fall the population is reduced to a minimum. There is little likelihood of this species becoming injurious on cultivated grain crops because of its wingless condition and its lack of tolerance of the interior valleys of the grain-growing area.

Prosopothrips cognatus Hood. This thrips has been referred to as the Kansas wheat thrips. Its eggs are inserted in young leaves of wheat or grass and hatch in from 6 to 10 days. The larvae develop in from 10 to 12 days. Pupation takes place in the soil at the base of the plants and lasts 10 to 13 days. The complete life cycle requires from 30 to 35 days. There are four to five generations a year. Both adults and larvae hibernate. The greatest larval abundance is in the spring at heading time but they also appear in numbers when volunteer plants appear in late summer, and again increase in late fall on early winter wheat. This species is wingless and therefore "swarming" at harvest time does not occur, as often is the case with *Limothrips cerealium* in the mid-western states.

The *Frankliniella* group of thrips, including the flower thrips, *Frankliniella tritici* (Fitch), *F. occidentalis* (Perg.), *F. moultoni* Hood, *F. fusca* Hinds, and *F. bispinosa* (Morgan) are well-known crop pests in North America but are relatively unimportant as grain and grass pests in spite of their local common names. Watts (1936) has reported that *F. tritici* shows a preference for grass, legumes, and members of the rose family and has found (1934) the larvae throughout the winter months on oats.

Other species found on grains and grasses in the western states: *Chirothrips manicatus* Hal., *C. mexicanus* D. L. Cwfd. and others in this genus, *Anaphothrips stanfordi* Moult., *A. longipennis* D. L. Cwfd., *Hercothrips fasciatus* (Perg.), *Thrips tabaci* Lind., and *Frankliniella minuta* (Moult.) are commonly taken in varying numbers on cultivated grain crops and grasses but do not occur in sufficient numbers to be of any concern. *Bregmatothrips venustus* Hood frequently becomes abundant on Bermuda grass, *Cynodon dactylon* (L.), particularly when the host grows in undisturbed mats in the shade. *Hercothrips bromi* Moult. is found on water grass, *Echinochloa crus-galli* (L.). *Haplothrips niger* (Osb.) is abundant on red clover particularly and in irrigated pastures at high elevations and mountain meadows, usually above 2500 feet in California. *H. fasciculatus* (D. L. Cwfd.) is found almost exclusively on wild buckwheat, *Eriogonum* spp.

Certain predacious species of thrips likewise are found in company with the insect fauna on these hosts; they are chiefly *Aeolothrips fasciatus* L., *A. bicolor* Hinds, *Leptothrips mali* (Fitch), and *Scolothrips sexmaculatus* (Perg.).

It will be noted that many of the species which are injurious to grains in Europe are found also in the United States. With the exception of the few scattered references of actual injury cited

above, little specific information is available on the losses caused by thrips on grain in North America. There is doubtless much more injury done by thrips to grains and especially to grass seed crops, than is realized. It is worth noting also that, while flax is commonly grown in the United States the flax thrips, *Thrips lini* Lad., has not yet been reported in this country. As was pointed out by the writer (1940) the cultural practices, especially in the far western states, of burning and plowing the grain fields after harvest discourages the establishment of thrips over large acreages. In Europe such cultural control recommendations are made for *Haplothrips aculeatus*, *H. tritici* and early harvest is suggested for the control of *Limothrips* and *Chirothrips*. Also, the normal, dry, hot months of July, August, September and often October, after harvest (in the far western states) force thrips to disperse and find other hosts on which to maintain themselves. Therefore, each winter and spring the thrips gradually migrate into the fields again and reach their peak in May and June. Oats, if grown in small acreage, frequently supports heavy infestations of *Chirothrips* and *Limothrips* which produce the typical blasting of the leaves and spikelets. Wild oats, *Avena fatua* L., in uncultivated pasture lands, which naturally reseed themselves, suffer severe injury (Fig. 1) from *Chirothrips*, *Limothrips* and particularly *Anaphothrips secticornis* (Tryb.). The latter species is wingless and is usually confined (with *Anaphothrips reticulatus* Moult. and *A. stanfordi* Moult.) to the cooler, shady portions of pastures and becomes very abundant in the coastal counties. Some seasons these *Anaphothrips* species so severely injure wild oats as to stunt the growth and permit very little reseeding. *Chirothrips aculeatus* appears to prefer foxtail to other pasture grasses and does not injure this host to the extent that *C. hamatus* does in northern Europe.

With the trend towards permanent pastures and the development and planting of new range grasses, however, it appears from our study of thrips and their habits, that, in years of favorable weather, this group of insects will assume greater importance. Many of the injurious species of the old world occur in North America and, given the right conditions these will increase in numbers along with certain native species. The case cited above, of the complete loss of fescue seed is an example of what can and may happen in the future as the plants and microenvironment in which thrips live are changed.

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Movement and Seasonal Populations of the Garden Centipede in Greenhouse Soil

CHAS. H. MARTIN,[1] *Oregon State College, Corvallis, Oregon*

The garden centipede, *Scutigerella immaculata* (Newport) has been known to be a pest on the underground parts of crops in the field and in the greenhouse for some time. One of the little understood fundamentals in the control of this pest is the movement of symphylids through the soil. It is difficult to trace the meandering course of individual symphylids from one point to another beneath the soil surface. For this reason the published observations on this subject have been more or less incidental.

In an unpublished manuscript submitted to the Ohio Agricultural Experiment Station on the use of gasoline for the control of symphylids, the writer presented data which indicated that under certain conditions symphylids do not regularly migrate seasonally to and from the surface of greenhouse soil. Also, data in this manuscript showed that symphylids do a considerable amount of traveling over the surface of the soil. Probably it is this surface-traveling population which reinfests the depopulated areas and attacks the roots of crops.

This paper discusses the movements of symphylids through greenhouse soil and some of the possible factors which are correlated with movement. Since the wanderings of the nymphal stages apparently determine to a degree the distribution pattern of the adult symphylid in the soil, the seasonal abundance of both adults and nymphs is discussed.

GENERAL TECHNIQUE.—Since it was not feasible to study symphylid movement by tracing marked individuals, the approach to the problem had to be indirect. Experiments with depopulated areas, systematic population counts throughout the year within the same areas, and observation of symphylid movement in cages correlated with observations on soil structure and with symphylid biology have led to some hypotheses on symphylid movement in the soil.

Soil samples for population counts were taken with a steel tube which was 6 inches in diameter. Each sample extended from the soil surface to a depth of 15 to 20 inches. Two or 3 inches of clay subsoil were included in each sample.

Population counts were made by examining small portions of soil spread on a 3-foot square of tar paper.

GREENHOUSE CONDITIONS.—At the time of these studies, many greenhouse growers practiced the following management of their greenhouses. Tomato plants were set in the rows of the last crop of lettuce in March or April. The lettuce was harvested 6 weeks after planting and the tomato vines continued to shade the greenhouse soil until August or September. Frequently the tomatoes were mulched with straw-manure. After the tomato vines were pulled, there was a 5 to 8-week fallow period. When the straw-manure mulch was left, the soil moisture was kept at the surface during the idle period. Soil without mulch dried to a depth of 2 to 6 inches. Lettuce or radishes were planted during the winter.

The friable greenhouse soil in the ground beds was the result of years of heavy manuring. Because varying amounts of manure had been applied to sandy soil, loam, and clay, the soil structure was exceedingly variable even within the same house. Most of the studies were made where the top soil was 10 to 20 inches deep. Below it was a stratum of either yellow or blue clay.

At a depth of 6 inches, the soil temperature usually ranged from 50° F. in the winter, to 80° F. in late August during the short fallow season. In the older and more drafty ranges the soil temperatures sometimes dropped below 50° F. and caused crop damage.

SOIL STRUCTURE AND SYMPHYLID MOVEMENT.—Descriptions of symphylid movements in the soil have been very general. Filinger (1931) observed that symphylids were unable to dig tunnels in the soil. He believed that their movements depended upon earthworm tunnels, "natural crevices in the soil" and "upon other agencies." Michelbacher (1939) and others have stated that soil structure is correlated with symphylid movement in the soil.

[1] The data presented here were collected while the writer was employed by the Ohio Agr. Expt. Station, Wooster, Ohio.

Since the symphylid is a delicate creature and is devoid of fossorial organs, one would hardly expect it to be capable of burrowing through soil. However, its extremely flat, flexible body suggests that it could move through very small spaces in the soil.

There are two general types of openings in the soil which offer pathways for symphylid travel. The first type is the gross cracks and fissures which lead directly or indirectly to and from the soil surface. Miles & Cohen (1935) report that such runways may be partially lined with silk by the symphylids.

The second and less obvious type is the network of interspaces between soil particles. Miles & Cohen (1935) remark that symphylids are able to move between soil particles at a slower rate than through tunnels. Movement through such interspaces is undoubtedly slow in much of the soil because there are no continuous paths which lead in any particular direction.

MOVEMENT THROUGH GROSS OPENINGS.—There are a number of types of gross openings in the soil. The rapid drying of the soil during the fallow season created wide, vertical cracks which were often a foot or more in depth and at times extended down into the clay subsoil. Cultivation immediately closed these cracks in the top soil. For a time the remaining portion of the cracks in the subsoil probably stayed open or were only loosely closed.

In some of the older ranges the symphylid populations were usually largest in the back part of the ground bed. In some houses the soil in this region was more moist than the soil in front of the bed during the growing season. When the soil was allowed to dry in the summer, the first deep soil cracks appeared in the back of the bed. Whenever these cracks were present, they offered those symphylids crawling over the soil surface a direct, vertical pathway to the subsoil. Because of the cracks, greater numbers of symphylids could enter the soil more easily in the back of the bed than in the front where the cracks appeared either later or not at all. Once at the bottom of the crack, horizontal movements would be slow unless horizontal paths were present. Thus, if a number of symphylids entered one crack, there would be a tendency for them to cluster in the subsoil at one spot for a time.

In addition to the deep cracks, the fissures formed by the irregular contact of the soil with the surfaces of retaining boards around beds, posts in the soil, and concrete foundations offered the symphylids direct, vertical paths to and from the subsoil.

An example of movement along such paths was observed around vertical tile-leads to the horizontal tile lines in the soil. Eight days after determining that the original symphylid population had been exterminated by steam sterilization, individual symphylids were found 6 to 8 inches below the soil surface in the soil fissures around the vertical tile-leads. These individuals had crawled (probably at night because of the hot, bright weather of August) over the soil surface from nearby untreated, infested beds and entered the uninfested beds.

There were horizontal cleavage planes in the subsoil which allowed considerable freedom of symphylid movement. Some were the result of environmental conditions, while others were created by man. Because the relatively loose top soil did not fuse with the compact clay, a network of irregular horizontal fissures was created which offered the symphylids considerable freedom of horizontal, underground movement. Large numbers of exuviae on the clay surface and in the soil just above it, indicated that the symphylids spend considerable time in this stratum.

Tile lines in the soil and their covering of cinders and other loose material also provided horizontal paths which symphylids could easily follow in the subsoil. In soil which had not been treated for several years, the population density was heaviest in the regions around the tile line and lightest in the areas between the tile lines.

Growers often provided a temporary network of horizontal fissures by burying a layer of clover chaff or some other organic material at a depth of 10 to 15 inches. Such material provided a loose mat which after settling was 0.5 to 1 inch deep. In the same house it might disintegrate slowly over a period of years, or within a year.

The writer obtained evidence that symphylids could quickly move for at least several feet along some of the horizontal fissures. This was accomplished by

concentrically squaring an area of fallow soil which laid on a clay hard-pan, with chloropicrin. A 10-foot outside square was treated and then the succeeding squares became smaller as the 3-foot square, untreated middle of the square was approached. After treatments, approximately 500 live symphylids were found crowded together in the untreated area in a fissure in the clay. Only 10 dead and alive symphylids were found in the large treated zone. Other similar experiments corroborated this interpretation.

MOVEMENT THROUGH INTERSPACES.—The soil openings described so far are either temporary or are restricted to definite areas in the beds and do not generally occur throughout the soil. Such temporary openings are probably of considerable importance for symphylid movement, yet they do not account for the widespread distribution of the large population of symphylids found free in the soil. Cage observations lead to the conclusion that these individuals follow the interspaces between soil particles.

The first studies of symphylid movement through the network of interspaces between soil particles were made in glass cages which were 3 inches in diameter and 10 inches tall. They were filled with alternate layers of fine sand which had interspaces too small for symphylid passage, and with finely granulated greenhouse soil which had interspaces sufficiently large for symphylid passage. There were three layers and each was 3 inches deep. Sometimes the sand layer was between the soil layers and in other cages the soil was sandwiched between the sand layers.

Many of the symphylids remained in the soil where they were originally placed. Others were found in the top or lower half inch of the sand layers, and some left webbing to a depth of 1 inch. The symphylids evidently had pushed their way into the surfaces of the sand layers but they never passed through them. Probably this was because the sand in the middle of the layer was too packed for the symphylids to push it aside for passage. Symphylids were able to push their way through the top inch of finely granulated greenhouse soil. Such soil was webbed as was the sand.

While in the above cages the symphylids were usually out of sight. The whole colony could be forced to travel through the interspaces in the soil to the sides of the glass cages by the introduction of a drop of chloropicrin.

Other cages consisted of boxes 6 by 6 by 30 inches. These were filled with finely granulated soil and lots of 100 symphylids were established at a point 2 inches from the bottom and 3 inches from one end of the boxes. Chloropicrin introduced near the symphylids caused all to leave the point where they had been placed. Some disappeared completely, a few dead ones were found, while others moved through the soil for a distance of 8 inches in 24 hours. This distance placed them beyond the zone of chloropicrin fumes in the soil.

Similar cages were set up without the introduction of chloropicrin. In some cases the symphylids remained in their original position, while in others they scattered through the soil for a maximum distance of 6 inches at a depth of 5 inches in 5 weeks.

The degree of freedom of symphylid movement through the network of interspaces in the greenhouse soil varied from one small area to another and from one year to another. In some soils symphylid movement was not possible. Such soil could be either loose or compact. Symphylids could not penetrate fine sand for more than an inch. Soil which contained considerable quantities of wood ashes did not granulate but retained its flour-like consistency throughout the year. The crops grown on such soil were never damaged by symphylids and none were observed in such soil. However, symphylids bred in the soil beneath the layer mixed with ashes.

Heavy soils did not permit symphylid passage through them until the soil was broken by cultivation, sudden drying, the growing roots of plants, or some other force. The compact yellow clay subsoil was usually uninfested, yet occasionally there were areas sufficiently broken to permit symphylids to live in the top 3 inches. Sometimes in the clay it was evident that the symphylids had followed the tunnels of other organisms or the holes left by the decay of roots.

Occasionally lone individuals were found at a depth of 12 inches or more in the clay and at a depth of 3.5 feet in other tight soils. There was no evidence to indicate how the symphylids had arrived at

the deeper depths. In the clay such individuals were usually in tiny air pockets which were about 0.5 inch in diameter. This diameter is larger than the holes left by roots in the clay. There was no evidence of a pathway to the pockets. A possible explanation for their travel through the compact clay is that soil cracks of the surface soil had continued into the clay. After the symphylids were lodged at the tip of the fissure, the seepage of water may have caused the passage to the fissure tip to seal.

VERTICAL DISTRIBUTION IN SOIL.—Symphylids were found to usually have a definite vertical distribution pattern in the soil. In table 1 the vertical distribution is shown for a number of variable conditions. In addition to the variables in the table, the soil depth ranged from 10 inches to 3 feet. Also, the population density was variable not only because of soil conditions but also because of the various degrees of control obtained in the several ranges where the data were taken. The data for the eight plots listed under the first subheading in table 1 show a population where no control was practiced.

Table 1.—The vertical distribution of the garden centipede.

TIME	TOTAL SAMPLES	TOTAL SYMPHYLIDS	PER CENT SYMPHYLIDS PER STRATUM 0–6 in.	6–12 in.	12–20 in.
Population trends in 8 plots for 21 months					
1940–42					
Dec. 20	24	88	3.4	14.7	81.9
May 22	24	7	0.0	18.5	81.5
June 22	24	22	0.0	22.7	77.3
July 22	24	59	6.7	38.9	54.4
Aug. 22	24[1]	62	3.2	33.9	62.9
Nov. 12	24	49	26.5	20.4	53.1
Feb. 12	24	40	12.5	30.0	57.5
April 12	24	111	18.5	30.5	51.0
June 20	24	147	16.3	39.5	44.2
Sept. 10	24[1]	296	24.9	66.4	8.7
Unmulched soil shaded by dead tomato vines and fallow for 2 to 6 months					
1940					
Sept. 17	48	1785	7.1	42.4	50.4
Oct. 3–6	147	2460	3.1	36.5	60.4
Nov. 12	36	550	0.5	46 9	52.6
Dec, 20	36	341	5.4	15.7	78.9
Soil fallow 1–6 weeks					
1941					
Sept. 4	18	133	4.3	41.8	53.9
23	20	84	1.2	77.4	21.4
26	20	71	4.2	86.0	4.2
Oct. 4	20	53	7.5	84.0	58.5
Soil with crops					
1941–42					
Oct. 15	100	937	28.7	10.7	60.6
Nov. 8	30	133	15.1	12.6	72.3
April 12	17	202	20.8	27.7	51.5

[1] Soil fallow 1–6 weeks; crops on soil during all other observations.

Miles & Cohen (1935) found in English greenhouses that symphylids usually infest the top inch of soil but sometimes they descended to a depth of 20 to 24 inches into clay or marl subsoil by means of soil-filled cracks. They were normally most abundant at a depth of 5 to 12 inches.

Kerns & Walton (1932) found numerous symphylids to a depth of 5 feet. The depth the symphylids were found depended upon the physical condition of the soil. The most suitable environment was porous, stony soil.

In the Cincinnati greenhouses the vertical distribution of symphylids follows a definite pattern which is independent of the variables listed previously and in table 1. The population in the top 6 inches of soil was less than 33 per cent of the total population at all times, table 1. Also, this population was usually not as dense as the one in the 6 to 12-inch stratum. The population below the 12-inch level was the densest more frequently than that in the middle stratum.

POPULATION GROWTH AND VERTICAL DISTRIBUTION.—Studies indicated that the density of a growing population of symphylids was greatest in the subsoil. Data on such populations were taken in plots depopulated within barriers and the trends of reinfestation were recorded up to 3 years. The plots were set up by first scooping out the soil to a depth of 18 inches. Then a 6-inch layer of fine sand was laid on the exposed clay to prevent upward movement of symphylids from the clay. The soil was replaced within tar paper barriers which surrounded the plots and extended from the soil surface downward and into the clay for 6 inches. The plots were depopulated with very heavy fumigations of gasoline.

Table 2.—Reinfestation of soil in barrier plots by the garden centipede.

DATE ESTABLISHED IN NOVEMBER	AVE. SYMPHYLIDS PER SAMPLE PER 6-INCH STRATUM IN SEPTEMBER 1940 0–6	1940 6–12	1941 0–6	1941 6–12	1942 0–6	1942 6–12
1939	0.2	1.5	0.2	2.3	0.3	6.6
1939	0.0	0.2	0.2	2.4	0.4	5.7
1940	—	—	0.2	1.3	1.0	5.1

Symphylids from adjacent infested plots crawled over the soil surface and descended into the soil of the plots. The barriers prevented any entry into the plots beneath the soil surface. The growth of populations at two levels in the depopulated plots were recorded for 3 years as shown in table 2. Each average was computed from 18 soil samples from each plot.

The data in table 2 show that the distribution of growing symphylid populations follows the same pattern as the data in table 1.

FACTORS CONTRIBUTING TO LARGE SUBSOIL POPULATIONS.—High soil temperatures in the summer and the drying of the soil caused the symphylids to disappear from the top soil when it was bare of cover. However these two factors had little or no effect on the vertical distribution of the symphylids in the greenhouses under observation because the soil was shaded most of the time by crops and by a mulch. Breaking the soil for crops loosened the soil so that symphylids could move with more freedom through the top soil. However, sampling symphylid populations before and after this operation indicated that the distribution in table 1 and 2 was unchanged. Also, population counts made before and after soaking the soil for cropping indicated that the symphylid vertical distribution was undisturbed by this second operation.

The first factor of importance which affects the vertical distribution of symphylids is their egg-laying habits. The initial population, which is the fountainhead of symphylid infestation, originates in the subsoil because the symphylid habitually lays its eggs in this region.

The absence of environmental factors affecting the vertical distribution of symphylids in the greenhouses lead to the assumption that the movement of symphylids in the soil is usually random. Random movement is a factor which would have the effect of concentrating the symphylid population in the subsoil. When a symphylid leaves the spot where it hatched in the subsoil, there are three general directions for movement in the soil: horizontal, upward, and downward. Hence, the symphylid in the subsoil has one chance in three of reaching the surface. Because less than 33.3 per cent of the symphylids reach the top 6-inch stratum, table 1, the chances seem to be actually less than one in three under the greenhouse conditions described in the opening paragraphs.

A third factor which would contribute to maintaining a larger subsoil population of symphylids, is the differential in the rate of movement in the top soil and in the subsoil. When the newly hatched symphylid drifts downward, its movements from one point to another are slow because of the relatively small number of continuous interspaces available. Downward movements finally have to cease because of the lack of interspace sufficiently large for symphylid passage.

As the symphylid drifts upward, its movements become less restricted and probably increase in speed and freedom as it nears the surface of the top 6 to 8-inch stratum where the soil is kept loosened by cultivation. Once in the top stratum, the symphylid can leave it much more easily and quickly than from the subsoil.

EFFECT OF MOVEMENT OF IMMATURE SYMPHYLIDS ON DISTRIBUTION.—The following observations suggest that the movements of the immature population of symphylids may have an influence on the vertical distribution of the adults in the soil.

First, the smaller, immature stages can pass through numerous openings in the soil which would block the passage of the larger adult. As a result, the immature stages may enter zones which it could not readily leave when it reaches the adult stage.

Second, items in table 3 indicate a move ment of only a part of the immature symphylid population toward the soil surface. Most of the population remains in the subsoil which gives a vertical distribution similar to the data for the vertical distribution in tables 1 and 2. In May none were observed at the soil surface, while only a few were found on or near the soil surface in June, table 3. The peak numbers of the immature stages appeared on or near the soil surface in July when 18 per cent of the total population was found in this region. At this time most of these individuals were on the soil surface in the damp mulch.

The increased numbers of adults in the subsoil during July is probably correlated with the maturing of individuals whose random movements in the immature stage

had not carried them to the upper soil strata.

Table 3.—The seasonal vertical distribution of immature and adult symphylids.

Month 1941	Depth of Samples in 8 Plots					
	0–6 in.		6–12 in.		12–20 in.	
	Im.[1]	A[2]	Im.	A	Im.	A
May 22	0	0	16	2	74	5
June 22	3	0	35	5	18	17
July 22	17	4	43	23	33	32
Aug. 22	3	2	16	21	13	39
Nov. 22	0	13	0	10	0	26

[1] Immature.
[2] Adult.

LONGEVITY, FOOD, AND MOVEMENT.—The ability of the symphylid to live for long periods and to feed upon decayed organic matter in the soil, would enable them to survive in the subsoil region (where they hatch) without ever leaving it and appearing at the soil surface.

Filinger (1930) kept individual symphylids as long as 2 years and 4 months. Michelbacher (1938) kept them as long as 3 years and 8 months. These individuals were fed lettuce leaves throughout their life. Miles & Cohen (1935) kept symphylids in soil in a laboratory for almost a year without the addition of plant material. The writer has kept individual symphylids in glass tubes for over a year. The only source of food was moist clay in some cages, and moist, rotted manure in others. Apparently the symphylids ate the clay since the alimentary canal was of the same color. The color of the alimentary canal of those living upon the rotted manure was a dark reddish brown. So, it is possible for the creatures to survive without live organic material. It would seem then that the fundamental reason for movement to the soil surface might be for dispersal rather than for food. Thus, symphylid depredations on crops could be only incidental to the species, even though very important to the agriculturalist.

This combination of longevity and apparent ability to live independently of live organic matter enables the symphylid to remain an almost stationary prisoner (as in the clay pockets) for long periods while it waits for the soil to crack and release it. Also, the symphylid may remain a prisoner in the soil within a limited area where it can move about freely but it is blocked from the soil surface for long periods. This seemed to be true in areas where the soil was of flour-like consistency.

OTHER VERTICAL DISTRIBUTION PATTERNS.—While the vertical distribution pattern shown in table 1 existed in most greenhouse soil where there was sufficient control to keep the symphylid populations at a relatively low level, yet sometimes this pattern was upset over large areas.

When areas are left untreated for several years the original distribution of the symphylid population may become masked by the sheer numbers of symphylids present. At such times the top soil populations may equal or exceed the populations in the strata below it. Under such conditions we might reason that spatial requirements were directing the excess population into the surface stratum where they could leave the soil and seek less crowded areas.

Unusual treatment of the soil sometimes directed the whole symphylid population in a movement toward the soil surface. This was observed on two occasions when the soil was soaked by filling trenches with water.

In one range the soil was only 10 inches deep, while in a second it was 2 feet deep. In both ranges the entire area of ground beds was broken by deep trenching. The trenches were filled with cold water in one range and with hot water in the second. Then the trenches were filled with soil and the crops planted without chemical treatment. In one range the heaviest population was in the top 6 inches of soil in an area of approximately 1000 square feet. In adjacent areas which had had similar treatment, the population was about evenly divided between the top soil and subsoil. In the second range the densest population was in the top 6 inches of soil over an area of several thousand square feet.

Summer fallow of unshaded soil will cause the symphylid population to disappear completely from the top soil. This was observed in soil which was bare of vegetation in July and August. Observations of this phenomenon and the fact that symphylids do but little damage to greenhouse crops in the spring and heavy damage in the fall, may have been the basis for the previous assumption that symphylids migrate downward in the spring and upward in the fall.

SEASONAL FLUCTUATIONS OF POPULA-

TIONS.—Michelbacher (1939) found several types of seasonal variations of symphylid populations at different soil levels. Greenhouse data will not be compared with his data because of differences in methods and in the phases of the environment.

Seasonal fluctuations of symphylid populations in Cincinnati, Ohio greenhouses were recorded over a 3-year period. From December 1939 to April 1942, on 14 occasions in one house the same eight plots, which were located randomly in the four quarters of a greenhouse, were sampled for the numbers of symphylids present.

Each 35-square-foot plot was located in the back of the ground bed. Three samples were taken from each of the eight plots for each observation date. These data are presented in table 4.

During the spring and early summer the six instars of the symphylids form successive, overlapping populations in the soil. For this discussion these instar populations are lumped as immature symphylids. The adults form a second major population. The two populations must be separated, as has been done in table 4, when seasonal fluctuations are studied. Otherwise the additive and subtractive effects of the immature populations will distort the trends of the adult population.

The sharpest correlations found in the data of table 4 is the close relation between the number of symphylids and the location of the samples. The totals for the 3-year period show that plot 8 had 13.9 times more symphylids than plot 1, and also 3.6 times more than plot 4. In addition, with two unimportant early season exceptions, the largest numbers of immature symphylids were found from season to season in plot 8. Hence it seems evident that some unknown factors were more favorable to symphylid reproduction in plot 8 than in any of the other plots.

The number of immature symphylids is not closely related with the number of adults found. For example, 54 adults and 71 immature symphylids were collected in May 1940, while in the same month in 1941, only 7 adults and 90 immature symphylids were collected.

Since the immature stages are most numerous in the summer, a corresponding increase in the numbers of adults would be expected after the immature population had disappeared. However, the population of adults in the fall is not equivalent to the numbers of nymphs found earlier in the season. In fact there is a strong tendency for the adult populations to appear to become reduced in the spring. For example, the December, 1939, population of adults was 5.3 times greater than the March, 1940, population; the December, 1940, adult population was 12.6 times greater than the May, 1941, population. From July 1941 to April 1942, the adult population did not fluctuate as greatly as it had the two previous winters. The sharp declines of the first two years were correlated with low outside temperatures. At these times the old, drafty greenhouse range could not be properly heated. The more uniform population of the third year was correlated with warmer winter temperatures outside.

IMMATURE POPULATIONS.—In the course of these studies about 8000 soil samples were dug for population counts and for insecticidal studies during all seasons of the year. Early instar nymphs were most numerous from April to July and the late instars from May to September. In general, immature individuals had disappeared in most areas of the greenhouse by November, except for occasional stragglers found throughout the winter.

Kearns & Walton (1932) report several overlapping generations in the spring and summer in England. Data in table 4 suggest that there were probably two generations in 1941 in Cincinnati greenhouses. In May and July there were peaks while in June the numbers of nymphs decreased.

There were times when the immature stage was prolonged because of adverse environmental conditions. In a range abandoned in July, large numbers of late instar nymphs and a few adults were found in dry, fallow soil in November. The symphylids had collected in the soil between the 5-inch level and the clay hardpan which was 12 inches beneath the soil surface. The moisture content of the soil and the clay ranged from 10 to 15 per cent. Unbroken, porous clods which contained symphylids were kept in glass jars at temperatures ranging from 50° to 70° F. Symphylids lived from November to February in soil with 10 per cent moisture and from November to April in soil with 15 per cent moisture. How long they might have lived under undisturbed field conditions is not known.

Table 4.—Number of symphylids per plot in areas untreated for a 3-year period.

DATE	STAGE	NUMBER OF SYMPHYLIDS PER PLOT								TOTALS
		1	2	3	4	5	6	7	8	
1939										
Dec.	A[1]	0	13	14	14	15	16	17	18	107
1940										
Jan.	A	5	9	9	9	10	10	11	23	86
March	A	0	1	1	1	1	5	6	6	20
	Im.[2]	2	0	0	0	0	0	0	0	2
May	A	1	2	0	2	18	20	9	2	54
	Im.	0	0	3	4	9	10	11	34	71
July	A	0	3	2	8	10	9	6	4	42
	Im.	0	0	1	2	4	5	9	20	41
Sept.	A	0	1	2	6	7	9	10	24	59
Dec.	A	1	4	7	11	13	14	18	20	88
1941										
May	A	0	1	0	1	0	2	0	3	7
	Im.	5	6	7	7	11	11	17	26	90
June	A	0	1	4	0	0	1	6	10	22
	Im.	0	1	1	2	2	4	16	30	56
July	A	1	6	2	9	5	13	13	10	59
	Im.	2	4	5	8	9	12	13	41	94
Aug.	A	2	7	1	4	0	2	4	39	62
	Im.	0	0	1	2	2	3	3	21	32
Nov.	A	1	5	5	6	6	7	7	12	49
1942										
Feb.	A	1	1	2	3	4	6	9	12	38
	Im.	2	0	0	0	0	0	0	0	2
April	A	1	2	2	2	3	7	7	11	35
	Im.	4	5	6	6	6	12	15	22	76
Totals		28	72	75	107	135	178	207	388	

[1] Adults.
[2] Immature.

SUMMARY.—Two types of openings in the soil offer symphylids pathways through the soil. These are the gross openings which may be in vertical or horizontal planes, and the network of interspaces between soil particles. The gross openings include cracks in the soil, the fissures formed by the irregular contact of the soil particles with the surfaces of retaining boards, posts in the soil, and foundations. Horizontal cleavage planes existed between the top soil and clay subsoil. Also, artificial horizontal planes were formed by the burying of organic material in the soil. Symphylids could pass through soil where interspaces between soil particles were sufficiently large but they could not enter sand, or soil of flour-like consistency, or into heavy soils unless fissures were present.

The symphylid population in the top 6 inches of soil was generally smaller than the population below this level. The habit of the symphylids laying eggs below the 6-inch level, differential rate of movement in the top and subsoil, the random movements of the symphylids in the soil, and the movements of the immature population influencing the distribution of the adults, contributed to the difference in the top soil and subsoil populations.

Factors contributing to the appearance

of large top soil populations are sheer numbers in soil not treated for several years, and soaking soil. Drying of the topsoil caused the population in this stratum to disappear.

The immature symphylids were most numerous from April to July. Because the distribution of the nymphal population is similar to that of the adult, and because the nymphs can crawl through smaller spaces than the adult, it is suggested that the movements of the immature symphylids may determine the distribution of the adult population to a considerable degree.

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The Control of the Rice Weevil and the Angoumois Grain Moth[1,2]

WALTER M. KULASH, *N. C. Agricultural Experiment Station, Raleigh*

The rice weevil, *Sitophilus oryza* (L.), and the angoumois grain moth, *Sitotroga cerealella* (Oliv.), are two of the most destructive stored corn pests in North Carolina. Both are abundant in the eastern or coastal plain sections of the state but the grain moth is the more serious pest in the Piedmont or western sections. Infestation of corn generally begins in the field, and the warm, humid conditions prevailing in most of the state favor the development of these pests in storage bins.

The presence of these pests in corn reduces its value for milling purposes and presents an annual control problem. The lack of proper storage facilities on many farms precludes the use of fumigation methods. The growing importance of hybrid seed corn production in North Carolina increases the need for controlling these pests.

Tests were begun in the fall of 1946 to check the effectiveness of various DDT formulations as controls for the rice weevil and the angoumois grain moth. In the first method of testing, weevils were placed in untreated jars containing treated shelled corn. This method is here called the laboratory jar test method.

In a second method of testing, treated corn was kept under normal conditions of storage. This method is referred to as the storage test. Checks were made on the degree of insect infestation at various periods of time after treatment.

LABORATORY JAR TESTS.—Shelled corn was treated in two different ways (1) by dusting with insecticidal dusts or inert powder at the rate of one part dust to 500 parts of shelled corn, by weight and (2) by a modified slurry method.

Five different dust treatments were used, and each treatment was replicated four times. Field corn, harvested a month before the treatment date, was used at the rate of 500 grams of shelled corn to each quart fruit jar. One-half gram of the test insecticide or some inert powder (to serve as a control) was added to the corn. Each jar was shaken for 2 minutes in order to distribute the dust material thoroughly throughout the contents of the jar.

One-half hour after the treatment of the corn, 50 freshly-collected weevils were placed in each jar. The metal cap of the fruit jar cover was reversed and placed on the jar opening and the screw ring was turned down just enough to keep the cap in place but not tight enough to keep air

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[2] Paper presented at the Cotton States Branch Meeting, Atlanta Georgia, February 5, 1948.

out of the jar. The materials used and the results obtained are listed in table 1.

In the modified slurry treatment, the seed was wetted by immersion for 1 minute in a liquid solution or dispersion of the test insecticide. The liquid was decanted after the immersion period and the seed was spread out to dry on clean paper before it was placed in clean quart-size fruit jars. Fifty weevils were added to each replicate and the jars covered. It should be noted that the angoumois moths were in the corn as it was harvested and that no additional moths were added to any of the treatments.

Dust and slurry-treated corn were kept in an unheated basement room. The temperature of the room averaged about 60° F. and was not subject to extreme variations.

The materials used in the modified slurry method of treatment and the results obtained are listed in table 1 as the numbers of weevils and moths breeding through at one and three months after treatment.

The number of weevils and moths listed in table 1 represent the total number found in the four replicates of each treatment. Originally, 50 weevils had been introduced into each jar of treated corn—or a total of 200 for the four replicates of each treatment. However, the total of weevils listed under the column headed "One month after treatment" in table 1 in most instances exceeds 200. This increase in the total is due to the emergence of weevil adults from larvae that had been in the corn before treatment was begun.

An examination of the corn 1 week after treatment showed that there was considerable activity of both weevils and moths, especially the latter. Two weeks after treatment, weevil activity was less intense in both the dust and in the modified slurry treatments, but moth development and activity was evidently progressing.

RESULTS OF LABORATORY JAR TESTS.—According to this method of testing, a concentration of DDT as low as 0.125 per cent, used in the modified slurry method of treatment, was effective in protecting shelled corn from the attacks of the rice weevils and angoumois grain moths up to three months after treatment. Evidently, this treatment did not completely control larvae of either the rice weevil or the angoumois moth in the seed corn itself, but the residue of DDT left on the corn was sufficient to control insects after their emergence from the corn.

Slurry treatments with concentrations of DDT at 0.25 per cent, 0.5 per cent, and 1.0 per cent had no more noticeable effect than did the 0.125 per cent concentration. DDT as a 5-per cent dust was about equal in effectiveness to 5 per cent wettable DDT used in the slurry method. Neither of these 5-per cent DDT treatments, however, can be said to be superior to any of the slurry treatments with the 0.125 per cent to 1.0 per cent concentrations of water miscible DDT.

A fungicide-DDT formulation, either as a dust or as a slurry, gave good control of both pests up to three months after treatment. The fungicide alone, either as a dust or as a slurry gave poor control of both weevils and moths.

Three months after treatment, there was a tremendous increase in the number of moths in both fungicide treatments, indicating that moth development had not been curtailed. The weevil population at the end of 3 months after treatment was practicailly nil. Indications are that the increase in moth development created a competition for food and space in which the moths won out. However, in the treatments with an inert clay dust, weevil development had surpassed that of the moths.

Graphite, as a dust, was ineffective in weevil and moth control. No moths were found alive in the graphite treated corn 1 month after treatment, but 2 months later (that is, 3 months after treatment), moths and weevils were very abundant. Corn treated with graphite was completely ruined 3 months after treatment, and no attempt was made to count the number of pests in these treatments. The same was true for the check treatment.

Germination tests of seed treated with DDT, a fungicide and fungicide-DDT indicated no loss in germination.

STORAGE TESTS WITH TREATED CORN.—In this series of tests, husked and unhusked corn was treated with 5 per cent DDT dust as well as with a spray of 5 per cent DDT made from a 25 per cent water miscible concentrate. Untreated husked and unhusked corn was used as the check treatment. Shelled corn was treated with 5 per cent DDT dust, one

part of dust to 1000 parts of shelled corn, by weight; also, in the modified slurry method with a 5 per cent water miscible DDT. The check treatment for shelled corn was one part of an inert dust to 1000 parts of corn, by weight.

Twenty-five ears of corn were used for each of four replicates in the husked and unhusked corn treatments. In the case of shelled corn, treatments were applied to four replicates of 500 grams of each.

Treated corn was kept in cages (not insect-tight) in an unheated upstairs loft where storage pests were normally abundant.

Infestation counts were made by selecting 10 ears at random from each of the ear corn replicates of husked and unhusked corn. One row of kernels in each ear was chosen at random, and the number of weevil and moth emergence holes in that row of kernels counted. About 1000 kernels were counted in each treatment where ear corn was used. In shelled corn, 100 seeds were selected at random from each treatment and the number of moths and weevil holes noted. Table 2 lists the results of these counts.

Husked and shelled corn was examined for rice weevil and angoumois moth damage at one, three and twelve months after treatment. Only one examination, was made of the unhusked corn, and this was at 12 months after treatment.

RESULTS OF STORAGE TESTS WITH TREATED CORN.—The angoumois moth was more abundant than rice weevil in all three types of stored corn. After one year of storage the best treatment was that with unhusked corn, treated with 5 per cent DDT spray. This had an infestation of 6.4 per cent. That treated with 5 per cent DDT dust had an infestation of 7.5 per cent. The untreated unhusked check treatment had a infestation of 19.3 per cent. Doubtless the presence of husks provided some protection against the moths and the weevils.

Shelled corn ranked second best on the basis of percentage of infestation. Here again the liquid 5 per cent DDT treatment had a lower percentage of infestation (13.5 per cent) than did the 5 per cent DDT dust (19.5 per cent). The check treatment had an infestation of 31.5 per cent.

Table 1.—Summary of results of dust and modified slurry methods of treatment of shelled seed corn for the control of the rice weevil, Sitophilus oryza (L.) and the angoumois grain moth, Sitotroga cerealella (Oliv.).

TREATMENT NUMBER	MATERIALS USED	NUMBER OF INSECTS BREEDING THROUGH			
		1 month after treatment		3 months after treatment	
		Weevils	Moths	Weevils	Moths
	Dusts				
1	5% DDT	271	351	48	14
2	fungicide-DDT[1]	251	425	27	24
3	fungicide	331	365	19	1,460
4	Graphite	268	228	Corn completely destroyed	
5	inert dust[2]	313	303	2,170	279
	Modified slurry				
6	0.125% DDT[3]	196	341	10	34
7	0.25% DDT	217	361	31	23
8	0.5% DDT	199	325	9	57
9	1.0% DDT	197	328	7	35
10	Check, water only	189	314	Corn completelyde stroyed	
11	5% DDT wettable	233	376	54	35
12	fungicide-DDT[4]	247	433	40	46
13	fungicide 1 lb. to 1 gal. water	232	441	20	1,472
14	inert dust, 1 lb. to 1 gal. water	316	346	1,368	420

[1] Made of equal parts of the fungicide *Arasan* and 5% DDT dust. *Arasan* (50% tetramethyl thiuram disulfide) manufactured by E. I. duPont de Nemours and Company.
[2] The Inert dust, *Attaclay* an inert insecticidal diluent, produced from the mineral attapulgite by the Attapulgus Clay Company, Philadelphia. Pennsylvania.
[3] DDT, modified slurries of 0.125% to 1.0%, made from water miscible 25% DDT concentrate labeled H-4, manufactured by the Charles Edwards Chemical Corporation, Philadelphia, Pennsylvania.
[4] Contains 1 pound per gallon of water of the mixture described in footnote 1 above.

Table 2.—Results of storage tests with husked, unhusked, and shelled corn treated with DDT dust and DDT liquid.

		Percentage Infestation After Treatment								
		One Month			Three Months			Twelve Months		
	Treatment	Moths	Weevils	Total Inf.	Moths	Weevils	Total Inf.	Moths	Weevils	Total Inf.
Ear corn husks on[1]	Check—no treatment	—	—	—	—	—	—	15.0	4.3	19.3[1]
	5% DDT dust	—	—	—	—	—	—	6.8	0.7	7.5
	5% DDT spray	—	—	—	—	—	—	5.8	0.6	6.4
Ear corn husks off	Check—no treatment	8.6	0.4	9.0	13.0	2.8	15.8	77.1	7.4	84.5
	5% DDT dust	3.9	0.2	4.1	9.1	1.7	10.8	15.2	1.9	17.1
	5% DDT spray	4.6	0.3	4.9	9.1	0.3	9.4	6.4	0.2	6.6
Shelled corn	Check[2]	5.5	6.5	12.0	9.0	13.5	22.5	20.0	11.5	31.5
	5% DDT dust	8.5	2.0	10.5	6.5	9.5	16.0	12.5	7.0	19.5
	5% DDT modified slurry	3.5	1.5	5.0	11.0	5.5	16.5	8.0	5.5	13.5

[1] Only the 12 months-after-treatment count was made for this group of corn.
[2] Inert dust, *Attaclay*, used as the check in shelled corn.

Untreated corn with husks off was the most attacked of all the treatments. Infestation at 12 months after treatment was noticeably more severe than at three months after treatment. Corn with husks off treated with 5 per cent DDT dust had an infestation of 13.1 per cent, which was about 25 per cent the infestation of untreated corn, 84.5 per cent infested. The liquid 5-per cent DDT-treated corn with an infestation of 6.6 per cent was noticeably less heavily infested than the dust treated corn, which had an infestation of 17.1 per cent.

The results of these tests clearly indicate the value of treating stored corn with DDT for the control of stored grain pests. It should be emphasized that the use of DDT is possible only for the treatment of corn to be used for seed purposes. DDT should not be used for any grain treatment when this grain is to be used later for human consumption or for stock feed.

Summary.—Two methods of testing various DDT formulations for the control of stored grain pests are reported. In the first method shelled seed corn was treated (a) with dust formulations at the rate of one part of dust to 1000 parts of seed corn, by weight; and (b) in a modified slurry wherein seed corn was immersed in liquid formulations for 1 minute. According to this method of testing, concentrations of DDT as low as 0.125 per cent were effective in checking the development of rice weevils and angoumois grain moths. Concentrations of DDT at 0.25, 0.5 and 1.0 per cent were not markedly more effective than 0.125 per cent DDT. All of the foregoing treatments, formulated from a 25 per cent water miscible DDT concentrate, were more effective than 5 per cent DDT formulated from a concentrated wettable powder. Dust treatment of shelled corn with 5 per cent DDT was slightly less effective than the modified slurry treatments with 0.125 per cent to 1.0 per cent DDT. A fungicide used as a dust or as a modified slurry did not protect seed corn from the angoumois grain moth. A DDT-fungicide mixture, dust or modified slurry, was effective in controlling moths and weevils.

In the second method of testing, husked, unhusked and shelled corn were treated with 5 per cent DDT spray or dust and then kept under normal storage for one year. Corn with husks on was less infested with moths and weevils than corn with husks off, both treated with 5 per cent DDT dust. This is based on checks made one year after treatment. A 5 per cent water miscible DDT spray afforded just as much protection to corn with husks on as it did to corn with husks off. The 5 per cent DDT spray was more effective on husked corn than was the 5 per cent DDT dust. 7-12-48.

Culturing *Chrysopa californica* and Obtaining Eggs for Field Distribution

GLENN L. FINNEY,[1] *University of California, Division of Biological Control, Albany*

Work was begun early in August 1947 for the purpose of developing an insectary method to supply many thousands of *Chrysopa californica*, Coq. eggs for use in proposed experimental field plots in 1948. The initial stock consisted of six female and four male *Chrysopa* reared from field-collected cocoons. Within five months using the eggs and mature larvae of the potato tuber moth, *Gnorimoschema operculella*,[2] as host material, this stock was expanded to over 4,000 adults. More than a half-million eggs had been produced by April 1.

Any description of methods now in use is essentially a progress report since it is likely that some changes and refinements will be made in the present techniques as investigations continue.

The oviposition unit consists of a one-gallon, cylindrical, waxed-cardboard carton 7 inches high and 6.75 inches in diameter. The bottom is smoothly cut off about 0.5 inch up on the side. The container is then reversed. The snug-fitting telescopic top now functions as the unit bottom. Over the cut end, now the top, a cloth is stretched and held in place by two rubber bands. The material used for the cloth tops is white gauze unsterilized bandage material obtained uncut in 10 yard rolls 36 inches wide—grade 60, mesh 32 by 28. This cloth is dyed black before cutting so that the eggs may be more easily seen. The entire wall of each unit is lined with wrapping paper, 40 lb. weight. The lining is fitted tightly against the side and fastened together at the lap with two pieces of masking tape. A disc of the same kind of paper is cut to fit snugly on the bottom and against the lining of the side.

Each unit is stocked with 50 male and 50 female *Chrysopa*. No attempt has been made to apportion sexes in the oviposition units. The sexes are extremely difficult to differentiate immediately after emergence except by close microscopic examination. After a few days of feeding the separation is not such a problem since the abdomen of the female becomes somewhat larger than that of the male.

During the first 2 weeks following emergence, the adults feed very heavily on honey presented to them in small droplets on brown, waxed-paper strips. Several strips are placed in each unit. They are fastened to the side-lining with tabs of masking tape.

When fed solely on honey there may be a light oviposition which will soon decrease to only a trace. If, however, at the end of 2 weeks the diet is supplemented with the honeydew excretion of common citrus mealybug, *Pseudococcus citri* (Risso), oviposition is induced within five days and production soon reaches a daily normal of about 150 eggs per unit. If, after reaching full production, the honeydew is withheld oviposition immediately decreases and falls off to a mere trace.

The honey is distributed over the waxed paper in the following manner. Sixteen sheet of paper about 5 inches wide are torn from a roll 20 inches or more in length. Honey is poured back and forth on one of them, forming an even pattern. The trail of honey should be about 0.175 inch wide and about 0.5 inch apart on the sheet. A second sheet is laid on the honey-covered one and both squeezed tightly together. The top one is then removed, turned end for end, and again pressed firmly on the first. These sheets are separated, and placed on two other sheets. The honey is thus transferred and spread from one sheet to another until all 16 have been used. The final 8 sheets are left face to face with the other 8 and stored in a cool humid place until ready for use. They are then cut into 2 by 5 inch strips. Each double strip is then pulled apart exposing the honey-covered surface. The honey soon forms many small droplets on the waxed surface. The strips are then fastened to the lining of the oviposition units with masking tape.

The following method is used to obtain the honeydew. Sprouted potato tubers infested with one-quarter grown common citrus mealybug are placed on a hardware-cloth screen (0.5 inch mesh) about

[1] The writer wishes to acknowledge the assistance of Charles Kennett in developing the method used in culturing *Chrysopa* larvae.

[2] The use of potato tuber moth for a host was suggested by S. E. Flanders.

2 inches above a sheet of brown waxed paper. In 3 to 4 days the sheet with the accumulation of honeydew is removed and hung in a dry place until ready for use. The debris may be brushed off as soon as the honeydew has hardened to the point where it will not smear. When ready for use the sheets are cut into 1.5 by 4 inch strips. One such strip per unit will induce oviposition. These should be replaced each time the units are changed or as soon as the honeydew has been devoured.

The honey and honeydew tend to harden when the relative humidity falls below 60 per cent The honey is more hygroscopic than honeydew. A ball of wet cotton is laid on a piece of waxed paper in the bottom of each unit to insure adequate moisture. The units are kept in a room having a relative humidity of 65 per cent and a temperature of 75° F.

The adults are relatively quiet during daylight hours. Most of the oviposition is accomplished after nightfall at which time they become very active. The stalked eggs are distributed singly and quite evenly over the cloth top and paper lining. A few are sometimes attached to the waxed paper strips and many are oviposited on the cotton ball should it become dry. Many loose eggs are found in the bottoms of the units, their stalks apparently having been severed by the adults. The eggs are often fed upon by the adults. Hatching occurs about 108 hours after oviposition when the eggs are held at 75° F.

Three times each week the adults are changed to newly prepared units. This should be done in the late morning hours when they are least active and are resting in the upper part of the unit. To accomplish this change the cylinder is lifted very carefully from its normal lid-bottom and slipped quickly into another. The adults are then anesthetized with carbon dioxide and fall into the clean bottom. This is done to prevent them from falling into the bottom containing loose eggs which adhere to their wings and are carried over into the new unit. This method also easily separates the dead adults from the living. The anesthetized adults are emptied from the clean bottom into a prepared unit where they remain until the next change.

The emptied unit is slipped back into its original bottom and set aside for a later count of mortality and egg production.

The egg-covered cloth tops are suspended with masking tape, each by one corner along a narrow stick 40 inches long. The egg-bearing surface is folded lightly together. Fifty or more may be hung from each stick.

The paper linings, still fastened in the form of cylinders, are slipped from the units and placed side by side in boxes. The linings may be compressed until the sides bearing the eggs nearly touch. If reasonable caution is observed, many of these may be packed in a small space without damage to the eggs.

The tops and sides are stored in a cool place until ready for field distribution. The eggs are counted and tabulated and the tops and sides are dated.

After the units are fully stocked the rearing of adults may be reduced to the number needed for the weekly replacements.

LARVAL CULTURE.—The unit used for culturing *Chrysopa* larvae is a tray 1.5 inches deep, 16 inches wide, and 40 inches long. The bottom is made of quarter-inch plywood and the sides of three quarter inch white pine. A groove one-sixteenth inch wide and three-quarters inch deep is cut in the middle of the top edge on all four sides. The top consists of a sheet of white muslin. It is stretched over the box and held in place by forcing the edges tightly into the groove with a putty knife, which should be dull with rounded corners to prevent tearing the cloth.

The hosts used in the culture of *Chrysopa* larvae are the eggs and also the mature larvae of the potato tuber-moth, *Gnorimoschema operculella*. The latter are processed with sodium hypochlorite, hot water and parafin, as described by Doutt & Finney (1947).

An egg sheet, exposed for 24 hours in a potato tuber moth oviposition unit in which 2,000 moths have been introduced is laid egg-side up on the floor of the *Chrysopa* culture unit. The edges of the sheet are taped firmly to the sides of the unit to prevent the larvae from penetrating beneath. About 850 to 900 loose *Chrysopa* eggs are scattered evenly over it. Since the larvae evidently prefer working in a rather snug environment another plain cloth is laid over the bottom. The cloth top of the unit is then clamped securely in place. The moth eggs should be

as fresh as possible. The *Chrysopa* eggs should be in the grey stage ready for immediate hatching.

Three and one-half days later the plain sheet on the bottom is removed and any larvae clinging to it are gently shaken off. In its place a second potato tuber moth egg sheet is laid egg-side down. This carries the same quantity of tuber moth eggs as the first sheet. The unit is then closed and set aside for about 3 days. The units up to this time should be kept in a room or within a cabinet having a relative humidity of about 80 per cent in order to prevent desiccation of the small *Chrysopa* larvae.

After 3 days the second egg sheet is rolled back and from 2,500 to 3,500 fully fed processed potato tuber moth larvae are distributed over the first egg sheet. The second egg sheet is then rolled back into place. A few tuber moth larvae are scattered over this also to feed the larvae that might wander to the top of the cloth. The *Chrysopa* larvae are given two additional feedings of processed tuber moth larvae at 2-day intervals. Cocooning which has begun at this time should be finished within 3 days. The entire culture period should be complete in about 15 days at 74 to 76°F. As soon as processed larvae are used as hosts the culture units should be changed to a room or unit held at 50 per cent relative humidity. Under conditions of higher humidity the host larvae tend to deteriorate rapidly and become unfit for food. The cocoons are removed and placed in cloth lined units; the same type of unit used for *Chrysopa* oviposition is used for emergence. The production of each unit will average 450 to 500 cocoons.

HANDLING OF ADULTS.—Emergence begins in about 8 to 9 days. Each day the emerged adults are anesthetized with carbon dioxide and placed in pre-oviposition units where they are first fed honey and then honeydew. After oviposition has begun they are used in the regular oviposition units to replace those that die each week. When handled individually the anesthetized adults are picked up by the wings with 6-inch forceps.

Mating is readily accomplished in the pre-oviposition units. The sex ratio seems to be quite favorable and has presented no serious problem.

Carbon dioxide alone, is employed as an anesthetizing or suffocating agent. Its action is less severe than that of ether.

The carbon dioxide gas is fed into the units through the cloth tops. A flow of gas for 1 minute, at a working pressure barely registering on a pressure regulator calibrated to 30 lbs. per square inch, should be adequate for anesthetizing the adults in each unit.

The gas should flow through a coiled section of copper tubing between the carbon dioxide cylinder and the regulator. The coil should be large enough to encompass a small electric light bulb and should be enclosed in a ventilated box. The temperature of the gas flowing through the coil should be raised to above 90°F. before reaching the regulator, otherwise the regulator would freeze up and cease to function properly.

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Tetraethyl Pyrophosphate for Control of the Periodical Cicada

A. M. Woodside, *Field Laboratory, Virginia Agricultural Experiment Station, Staunton*

The 1948 appearance of Brood V of the periodical cicada, *Magicicada septendecim* (L.), in central Virginia provided an opportunity for the testing of some of the newer insecticides against this insect, which has shown resistance to a wide range of insecticides. Various materials were applied as ground sprays to determine whether any of them might prevent emergence of the cicadas or kill them on emergence. The same materials and others were tested against the cidacas in the laboratory and as orchard sprays.

Ground Sprays.—Cicadas began to emerge on May 10, but they did not appear in very large numbers until May 16. On May 12 ground sprays were applied in the Ranch Orchard at Buffalo Gap in Augusta County. Each material was applied to the trunks and larger branches of seven mature apple trees, and to the undergrowth and soil beneath the same trees. About 25 gallons of spray were used per tree. The following materials were tested in this way:

DDT (50 per cent), 4 lbs. per 100 gallons
Benzene hexachloride (6 per cent Gamma isomer, 44 per cent other isomers), 4.5 lbs. per 100 gallons
Ditolyl trichloroethane (25 per cent), 6 lbs. per 100 gallons
Chlordan (40 per cent), 3.75 lbs. per 100 gallons
Parathion (25 per cent), 3 lbs. per 100 gallons
Chlorinated camphene (25 per cent), 6 lbs. per 100 gallons.

During the two days immediately following the application of these sprays it appeared that the chlordan and the benzene hexachloride were preventing or retarding emergence of the cicadas. There were fewer cast skins on and under the trees sprayed with these materials than on and under the check trees and those sprayed with other insecticides. On May 14, a second series of trees was sprayed with each of these two materials. No retarding effect on emergence of cicadas was noticed following these sprays. By May 17, it was apparent that neither of the materials had reduced the emergence of cicadas where they had been used.

Laboratory Tests of Insecticides.—On May 16 and the days immediately following tests were run in the laboratory with these insecticides and with hexaethyl tetraphosphate and tetraethyl pyrophosphate. Each material was tested by spraying four cages, each containing 25 cicadas. In some cases a test was repeated, giving eight replicates. The cicadas to be sprayed were placed in a cage of hardware cloth, and the spray was applied from four sides with a compressed air sprayer to insure thorough wetting of the insects. The excess spray was removed by a vigorous shaking of the cage, and the cicadas were transferred to a dry battery jar and supplied with fresh foliage. The battery jars were placed in the insectary, and the cicadas were examined after 24 hours to determine their condition. The check cages of cicadas were sprayed with tap water in the same way as the others. The results of these tests are given in table 1. Tetraethyl pyrophosphate was the only insecticide that showed much promise. It was just as effective at 4 ounces per 100 gallons as at 1 pint per 100 gallons.

Orchard Tests of Insecticides.—On May 21 small plots of apple trees in the Ranch Orchard were sprayed with tetraethyl pyrophosphate (35 per cent) at 4 and 8 ounces per 100 gallons, and with benzene hexachloride, parathion, and chlordan at the rates used in the insectary tests (Table 1). Observations of the cicadas after spraying indicated that it would be impossible to determine whether benzene hexachloride, parathion, or chlordan had any value against the cicada without the spraying of relatively large blocks of trees. The cicadas moved from tree to tree so rapidly at temperatures above 70° F. that the population of a tree might change completely within two or three hours. As a result of this movement any cicadas that died as a result of the spray would be widely scattered before they died, and the sprayed trees would have been repopulated by those that migrated from the surrounding unsprayed trees. Examination of the sprayed plots on the day following the spraying failed to show any dead cicadas that could be

Table 1.—Results of spraying periodical cicadas in cages. Results of four tests with 25 cicadas each. Staunton, Virginia, May, 1948.

Spray, Amounts per 100 Gallons	Condition of Cicadas After 24 Hours		
	Dead	Moribund	Normal
Ditolyl trichloroethane, (25%), 6 lbs.	44	11	45
Parathion (25%), 3 lbs.	47	11	42
DDT (50%), 4 lbs.	64	5	31
Benzene hexachloride (6% gamma isomer, 44% other isomers), 3 lbs.	16	47	37
4.5 lbs. (8 tests)	45	96	59
3 lbs.; Spreader, 1 pint	37	46	17
Chlordan (40%), 3.75 lbs.	52	9	39
Chlorinated camphene (25%), 6 lbs. (8 tests)	93	39	68
Tetraethyl pyrophosphate (35%, related phosphate esters, 65%), 1 pint	97	0	3
8 ozs.	95	0	5
4 ozs.	95	0	5
3 ozs.	91	0	9
Hexaethyl tetraphosphate (100%), 1 pint (8 tests)	143	0	57
Check, sprayed with water (8 tests)	6	1	193

assumed to have been killed by these sprays. The population of cicadas in the sprayed trees was not lower than in unsprayed trees nearby.

Tetraethyl pyrophosphate used at the rate of 8 ounces per 100 gallons gave an entirely satisfactory kill of the cicadas, but the 4-ounce rate was slower in its results, and there was doubt that it was giving as complete a kill as the 8-ounce rate. On May 22 several tanks of spray containing 6 ounces per 100 gallons were applied in the Ranch Orchard. On May 24, 2 days later, the block of trees sprayed with this solution was almost entirely free of cicadas except around its borders. The kill was estimated to have been almost complete.

SPRAYING ORCHARDS.—As a result of these experiments the manager of the Ranch Orchard decided to apply tetraethyl pyrophosphate to the entire orchard. The first spray was started on May 25, the day after the first eggs were noted, and was completed on May 28. As there were still a few cicadas emerging, and as others constantly flew into the orchard from nearby woods, a second spray was started on June 1 and completed on June 5. When this spray was completed the main body of this orchard was almost completely free of living cicadas, although they continued to migrate into those parts of the orchard near woods. Additional sprays were applied to these parts of the orchard until some small areas had been sprayed five times with tetraethyl pyrophosphate. Only two sprays were applied to most of the orchard. The spraying of the orchard was started with a preparation containing 35 per cent of tetraethyl pyrophosphate and 65 per cent of related phosphate esters. When the local supply had been exhausted the material next obtained contained 40 per cent of tetraethyl pyrophosphate. Both preparations were used at the rate of 6 ounches per 100 gallons of spray.

The apparently aimless flying of the cicadas and the consequent rapid repopulation of small areas that may have been freed of them make the use of small plots impractical in the testing of insecticides against this insect. For this reason it is difficult to make a comparison of sprayed and unsprayed trees on an exact basis. Observation of the situation in the Ranch Orchard and in the Eager Orchard, about a mile away, where no spraying was done against the cicada, demonstrated the efficiency of the spraying in the reduction of the injury caused by oviposition. In order to obtain some basis for comparison of the infestations in the two orchards the cast skins of cicadas were collected and counted under three representative trees in each of these orchards on May 25. On June 29 a terminal branch 12 to 30 inches long was cut from each of 100 trees in each orchard and the cicada egg punctures in these branches were counted. The results of these counts are shown in table 2. There had been a heavier emergence of cicadas in the Ranch Orchard, but the oviposition was 83 per cent lower there than in the Eager Orchard. Table 2 also contains figures showing the oviposition in branches taken from trees in the two rows next to heavily infested woods at the edge of the Ranch Orchard. Oviposition was nearly three times as heavy here as in the center of the orchard, showing the

Table 2.—Number of cast skins of periodical cicada per tree, and number of egg punctures per foot of branch, Ranch Orchard and Eager Orchard, Buffalo Gap, Virginia, May and June, 1948.

Orchard	Treatment	Cast Skins per Tree	Egg Punctures per Foot of Branch
Eager	unsprayed	1640	25.2
Ranch, center	2 sprays	2106	4.5
Ranch, border	5 sprays	—	11.4

effect of persistent migration from the woods.

Observations in other orchards where one tetraethyl pyrophosphate spray was applied showed that oviposition was 40 to 50 per cent less than in nearby orchards where no such spray was used. Observation at the time of spraying showed that high-powered machines which deliver a large volume of spray and cover the trees relatively quickly were much more effective than lower-powered outfits which require more time to cover a tree. Slow coverage permits the escape by flight of cicadas that would have been wetted by quicker coverage. Spray applied from the top of the sprayer or from a tower was more effective than that applied from the ground. When spray entered a tree from below the shaking of the branches caused the flight of some of the cicadas from the top of the tree before they could be wetted.

Tetraethyl pyrophosphate spray gave results quickly, and these results could readily be observed. After being wetted by the spray many of the cicadas showed signs of agitation by clinging to twigs and branches and vigorously fanning their wings. Such activity was not often observed after the application of any of the other sprays. Very few cicadas flew from the trees after they were sprayed, although there was a constant movement of the insects over and around these trees. Within 10 minutes after being sprayed with tetraethyl pyrophosphate at 6 ounces per 100 gallons some individuals began to drop to the ground. This dropping continued steadily for about two hours, and a few continued to drop for 24 hours. After falling to the ground the cicadas fluttered and attempted to fly. Few of them seemed to be able to crawl, showing lack of coordination in their movements. Cicadas which flew into the sprayed trees were not noticeably affected by the tetraethyl pyrophosphate, although some of those that dropped from the trees long after the application of the spray may have come into the trees after they were sprayed. Flying cicadas showed a tendency to avoid trees sprayed with tetraethyl pyrophosphate until after the spray had dried.

The value of this spray depends to a considerable extent on the rapidity with which the orchard can be covered. The cicadas are flying whenever the temperature is high enough, and if too much time elapses between the beginning and the finishing of the spray many will have migrated from the unsprayed to the sprayed part of the orchard, thus escaping the effects of the spray.

Tetraethyl pyrophosphate seems to be about equally effective at all temperatures between 50° and 80° F. Temperatures ranged between these extremes during the spraying of the Ranch Orchard, and little difference was noted in its effect. The dropping of the cicadas began after about the same length of time at the lower as at the higher temperature. The death of the affected insects was somewhat slower at the lower temperature, but the ultimate kill was about the same. Fewer cicadas escaped by flying at the lower temperatures. Even the presence of heavy dew on the foliage did not apparently decrease the efficiency of the spray.

Little opportunity was available for observing the effect of other spray materials on the tetraethyl pyrophosphate. It was observed, however, that the addition of flotation sulfur and DDT decreased its effectiveness. One apple grower added 8 ounces of tetraethyl pyrophosphate per 100 gallons to a spray containing 10 pounds of flotation sulfur and 2 pounds of 50 per cent DDT. Three hours after the application of this spray many of the cicadas which had been wetted by it, as shown by dried deposits, were still active. Many were killed, but the spray was much less effective than when tetraethyl pyrophosphate was used alone.

CONCLUSION.—These results indicate that tetraethyl pyrophosphate has definite value as an insecticide against the periodical cicada. Further investigations would be justified, particularly in the protection of young orchards against the oviposition of the cicada. It is probable that control of the cicada at one appearance may result in permanently freeing the area from this insect, especially in locations some distance from woodlands or other sources of reinfestation.

Important Sunflower Insects and Their Insect Enemies

A. F. Satterthwait, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Several species of insects attack sunflowers and thus limit their production for seed or oil. Information obtained on some of these insects has already been published (Satterthwait & Swain 1946, Satterthwait 1946). Four other species which have also been found to be of some importance as sunflower pests and their natural enemies are discussed in this paper.

The Cocklebur Billbug.—The cocklebur billbug, *Rhodobaenus tredecimpunctatus* (Ill.), is distributed generally throughout the United States. Its host plants include wild and cultivated sunflowers, *Helianthus annuus* L. and *H. mollis* Lam.; Jerusalem artichoke, *H. tuberosus* L.; great ragweed, *Ambrosia trifida* L.; bitter weed, *A. artemisiifolia* L.; cocklebur, *Zanthium canadense* Mill.; and *Dahlia* sp. The billbug is single-brooded. The adult leaves the pupal cell before winter and hibernates presumably in trash. The adults may be taken throughout the year, and the larvae from June to September.

The adult greatly resembles corn billbugs (weevils of the genus *Calendra*) in shape and hardness of exoskeleton. It is about 10 mm. long and brilliantly red, with 13 or fewer black spots on its back, and is blackish beneath. The adult is extremely quick in its movements, and it may as quickly feign death and fall out out of sight. It sometimes stages dancing, bowing, and swinging antics by shifting postures of head, fore legs, and hind legs grotesquely, and when ready to go may leap suddenly into swift flight.

The adults were observed feeding on *Helianthus annuus* and on *H. mollis*. Excavations in the sunflower were in the stalk near the top, in the leaf at the junction of leaf blade and petiole, and in the petiole. In *H. mollis*, a much smaller plant, excavations were in the midribs of leaves and in vertical slits in the stalks. The work of the adults in the commercial sunflower usually is inconspicuous, but in *H. mollis* it is very disfiguring and sometimes kills the flowering parts or the entire stalk.

In the St. Louis, Missouri, area oviposition began by May 28. In the field, the preferred place appeared to be on upper leaf surface at its junction with the petiole, and in cages, singly in some of the feeding excavations in the stalk rather than in the leaf or petiole.

The eggs range in size from 0.51 by 1.07 mm. to 0.67 by 1.44 mm. They are white, the ends equally rounded, and the sides straight. They may hatch in less than 4 days.

The larva at hatching has a head width of about 0.46 mm. A larva having a head width of 1.56 mm. was 9 mm. long and 1.94 mm. thick. Larvae may attain a head width of 1.87 mm. and a total length of 13 mm. The larva eats its way through the length of the petiole into the stalk, if the egg is laid in the leaf. Sometimes it works upward in the stalk before working downward. As it moves downward, it cuts openings through the stalk wall and ejects accumulations of frass. Near the surface of the ground, above or below, the mature larva usually constructs a pupal cell within its excavation, packing shredded stalk fibres an inch or more both above and below the cell. The larva may complete its growth in about 10 weeks.

Sometimes this billbug damages 100 per cent of the stalks of sunflower in an entire field. The loss in seed yield, however, is not commensurate with the earlier appearance of destruction in the stalks. In a dahlia garden of several hundred potential prize-winning plants, some were killed completely by this billbug and many others mutilated.

The pupa is about 10 mm. long and 3 or 4 mm. wide, creamy white until nearing maturity. The setal arrangement is similar to the general arrangement on pupae of the corn billbugs. Of the spiracular setae, one is near the spiracle and one at the rim of the pronotum; the dorsum of the eighth abdominal segment has no setae. The pupal period is sometimes less than 5 days. Thus, the life cycle is completed in less than 3 months.

Four puparia of the false stable fly, *Muscina stabulans* (Fall.), were found in one pupal cell, and were believed to be parasitic on the cocklebur billbug.

The elimination of infested host plants, such as cocklebur, great ragweed, bitter

weed, iron weed, joe-pye-weed, thistle, rosin weed, and leaf-cup weed, during the growing season from the area to be planted the following year should help to control this billbug. Since the beetles leave their pupal cells soon after becoming adults, and hibernate presumably in trash, the elimination of trash should aid in control.

THE SUNFLOWER BUDWORM.—The sunflower budworm, *Suleima helianthana* (Riley), is widely distributed from Maryland to Texas and California. Its host plants include the common sunflower, Jerusalem artichoke, bitter weed, and *Coreopsis grandiflora* Hogg. This budworm has two or more broods each year. Apparently the species wintered as mature larvae, pupated early in the spring, and reached the adult stage in time for the first brood of larvae to be small but well started by mid-June and to yield adults by July 4. Adults continued to appear until October 8.

The adult has a wing-spread of 15 to 20 mm. It is ashy-gray; the forewings have two quadrate blackish patches on the inner margin, with a blackish dash and a white triangle at the apical angle.

In the field, adults were occasionally observed resting on plants or flying in the automobile-headlight beam thrown into the sun flower field at night. In cages, eggs were laid variously on upper and under surfaces of leaves, both along and remote from the ribs and veins. In the field, the attacks on terminal and axillary buds imply that eggs may be placed in crevices about buds and bracts, as well as on leaves. The damage to the crop is greatest when the terminal buds of small, young plants are the chief attraction. When the tender, attractive axillary buds have developed, infestation in these is increased and the attack on the terminals reduced.

The eggs are about 0.3 mm. wide, 0.5 mm. long, and about 0.2 mm. thick, and are strongly attached to the plant surface by a secretion. They are distinctly marked with rounded-hexagonal impresses —concave in end areas, convex elsewhere —arranged in alternating rows. The texture of the egg shell is that of delicate, waterproof, transparent paper. In cages in mid-summer as many as 130 eggs were laid by 1 female, and incubation required about 4 days.

The full-grown larva is 8 to 11 mm. long, with head width about 1.27 mm. and body width about 2 mm. The cuticle is white, beset with little red-brown setae flared at the base. The head and cervical shield are dark brown, and the anal plate is pale brown.

The newly hatched larvae were seen feeding as leaf miners, webbing and entering at a leaf rib, or webbing and feeding for a time on parenchyma on one leaf surface. At each feeding point the larvae produce gunpowder-like frass. The older larvae enter the bud, leaf axil, or bract, and burrow in the leaf stem, plant stalk, bracts, receptacles, and seeds. Some flower heads are misshapen, as if galled. Blackish frass, bound together with silk, in due time marks the entrance of each larva into the plant. When mature, the larva spins a white silken cocoon close to the opening into the excavation, and protects the cocoon by the silk-bound mass of frass.

The pupa is about 1.32 mm. wide and 5 mm. long, and often larger. The sheaths of the upper and under wings and of the third pair of legs reach to the middle of the fourth abdominal segment. The ventral surface is smooth. The head and the dorsum of the first abdominal segments are unarmed, the dorsum of the second abdominal segment is nearly smooth, and the other segments are heavily armed with spines.

The life cycle requires about 50 days; the egg stage requires about 4 days, the larval stage about 40 days, and the pupal stage about 6 days.

One predator and several parasites were reared from immature stages of this budworm. They are *Hydnocera pubescens* Lec., *Lixophaga variabilis* Coq., *Siphophyto floridensis* Towns., *Helicobia helicis* Towns., *Muscina stabulans*, *Microbracon caulicola* Gahan, *Microbracon* sp., *Apanteles epinotiae* Vier., *Pristomerus eurypty-chiae*. Ashm.

Since the species winters in the larval stage in excavations in sunflower-plant trash, the destruction of such trash by deep plowing should afford substantial protection to cultivated crops of sunflowers.

THE SUNFLOWER-HEAD CUTWORM.—The sunflower-head cutworm, *Stibadium spumosum* Grt., was taken throughout the Missouri-Illinois areas under observation, in sunflowers and in a dahlia-flowered hybrid at St. Charles, Missouri. There is

only one brood a year. It winters in the pupal stage. Collections of larvae were made from June 17 to September 29. One pupa, which wintered out-of-doors, yielded an adult on September 4. Adults were taken in light traps in July and August.

The adult has a wingspread of about 35 mm. and closely resembles the moth of the stalk borer, *Papaipema nebris* Guen. The general color is soft brown, with a single distinct diagonal line of yellowish white. Some scales are tipped with white, giving the wings a frosty appearance. There is a prominence on the face between the eyes which often becomes abraded, when it appears as a cup with a sharply elevated rim about 0.6 mm. across The ovipositor is prominent. In the field the moth was observed only at rest.

Numerous eggs were found in sunflower heads on August 4, but were not proved to be of this species.

When the newly hatched larva begins to feed in the sunflower head, it forces its frass to the surface of the flowers, leaving the crowns of the achenes in position, thus concealing itself. Under this cover the larva eats away the kernels and the chaff, leaving a smooth area about the size of a silver dollar on the receptacle. Larvae that were forced to drop to the ground before maturing sought new heads on which to complete feeding. One displaced larva spun a silken thread to let itself down. Normally each larva completes its feeding in the one area. Little evidence was found of change of feeding area or of cannibalism. However, when two larvae were placed together in a small salve tin, one devoured the other. Sometimes there were as many as 20 larvae feeding in one sunflower head, without conflict.

The full-grown larva is 20 to 25 mm. long and 5 or 6 mm. thick, robust, with skin uniformly finely pebbled or embossed Magnifications show that the skin is closely beset with fine points. The head reaches a width of 3.57 mm., and is usually red brown. The epicranium is marked with two to seven or more clumps of oval, red-brown checkered spots, the clumps arranged approximately in rows. The cervical shield is as wide as the head, as long as the segment, and brown. The caudal plate is large, semicircular, and dark brown. The larva burrows into the soil to pupate. It forms a cell with a very hard wall composed of soil and body fluid. The larva requires about 30 days to complete its feeding. In many sunflower heads 15 to 35 per cent of the seeds are destroyed, while in some more than half are destroyed by this insect. In the New Madrid, Missouri, area most of the heads were infested with larvae of this species.

The pupa is about 12.4 mm. long and 5.7 mm. wide. The thorax and wing covers are tawny-olive, except the collar, which is apricot-buff; the abdomen is apricot-buff. There are no spines or setae. The antennae rise high on the head, cover part of the eyes, and reach the middle of the third abdominal segment. The labial palpi and wing pads reach just across this third segment. There is a tendency for the caudal end of the female pupa to be much swollen. The pupal stage requires about 10 months; the average for 14 pupae was 293 days, a range of from 205 to 341 days.

The life cycle requires nearly 12 months

Five species of insects were reared as predators or parasites of the larve. They are *Hydnocera pubescens*, *Lixophaga variabilis*, *Helicobia helicis*, *Microbracon mellitor* (Say), and *Chelonus altitudinus* Vier.

This sunflower-head cutworm burrows into the soil, soon pupates, and lies in its cell nearly 10 months. Plowing the ground should destroy most of the pupae, especially if the plowing is done after the sunflower harvest and before winter. The weather should supplement the plow in killing the pupae.

THE SUNFLOWER-SEED MIDGE.—The sunflower-seed midge, *Lasioptera murtfeldtiana* Felt, is distributed over the sunflower growing sections of Kansas, Tennessee, and Illinois. It infests Jerusalem artichoke and the sunflowers, *Helianthus annuus*, *H. grosseserratus* Martens, *H. nuttalli* Torrey & Gray, *H. uniflorus* Nuttall, *H. chrysanthemiflorus* Hort. *ex* Bailey and a dahlia-flowered hybrid.

The number of broods per year is not well defined. The species was not carried through one generation or one year. According to observations in the general vicinity of St. Louis, the only stage surviving the winter is the mature larva. Some larvae of the previous year were alive in stored heads as late as September 14, but one larva that had been kept over winter in the laboratory became adult on April 24. Other adults did not emerge

until August 1 and 2 from collections made the previous year. Adults were issuing in the field at New Madrid from August 2 to 20, and as late as November 19 from sunflower heads of the current season. Oviposition was observed at Webster Groves, Missouri, on August 26 and 28, and at Fairmont City, Illinois, on October 7.

This seed midge is about 2 to 2.5 mm. long, brown, and decorated with silvery scales at margins of abdominal segments. At the moment the adult issues, its wings bear dark scales. These are soon lost and the wings are then hyaline. The abdomen of the gravid female appears red, by reason of the contained red eggs.

Thirty 9 by 35 mm. glass vial cages, each with at least 1 adult female and 1 or more sunflower florets, were made up for observation of oviposition behavior. The female extrudes the ovipositor for a length greater than that of her head and body. The ovipositor is fleshy and cannot pierce any part of the flower. Eggs are placed in crevices in the head and in the florets. The interior of the corolla, especially after the stamen tube has been projected, is the preferred place. No eggs are laid in unopened buds. In the field, 7 eggs were found in 1 corolla and 16 eggshells in another. In cages, 1 female filled a corolla with eggs in 29 minutes, another in 19 minutes, and another in less than 15 minutes. Where as many as three females were in one cage, they seemed to prevent each other from depositing any eggs. In cages the adults lived only 2 or 3 days.

The egg closely resembles that of the hessian fly, *Phytophaga destructor* (Say), in size, form, and color. One female was dissected and found to contain 85 well-developed eggs in one ovary and 72 in the other, and several undeveloped spherical eggs. Hatching in less than 46 hours was observed.

At the moment of hatching the larva is red and about four times as long as thick. As the larva leaves the egg shell, it migrates to the ovary, burrowing through any part of the flower, and at any angle through the juicy achene. Several larvae have been observed penetrating the hull of a single achene. For a short time the cells made by the larvae may be seen through the tender walls of the achenes. Once in the achene, the larva becomes whitish, first its middle, then its ends.

One young sunflower head collected from the field and sliced completely through the stratum of achenes showed such a multitude of larvae of this midge as to indicate that each achene was or soon would be infested. Other heads also were heavily infested. Some tender achenes readily showed the cells made by the larvae that had recently entered, especially after the corollas were removed. Even cells of half-grown larvae were recognizable, and one could determine whether the form was that of larva or pupa. As many as 54 cells were observed thus in achenes in one 4-inch head, and these may have been less than 10 per cent of the infestation in that one head.

When full grown the larva is about 2 mm. long, nearly white, distinctly segmented, about 2.5 times as long as wide, and somewhat flattened. The larva pupates within the achene, sometimes within a pocket in the lining of the achene.

Breland (1939) noted that some midge larvae were found in normal achenes and might be distributed with seeds. In the writer's experience essentially every achene entered by a midge larva is of necessity embryonic, else the larva could not enter. At this stage the embryo resembles a tiny droplet of water. The larva generally so affects the embryo that its walls collapse and dry up, and the achene hull is aborted. Such achenes are light and frail. They show no external evidence of insect attack and are blown away as chaff at threshing. Thus the work of this midge is so insidious as to escape the attention even of most growers or fanciers of sunflowers.

Breland noted that "if a sunflower head possesses black seed, infested seed can sometimes be distinguished from healthy ones by their brownish color, but this is not invariable." The writer observed in unthreshed heads of a dahlia-flowered hybrid sunflower a telltale growth of pubescence on the blossom ends of achenes infested by this midge.

Frass produced by this midge larva was inconspicuous. Occasionally a larva of some other species was found in the same achene with a midge larva, leaving visible frass.

The pupa is about 2.5 mm. long, varying in color from white to black as it develops. There is a prominent bifid, chitinous horn on the front of the prono-

tum. A coat of short, stout chitinous spines clothes the abdominal tergites. The abdomen is free to move vigorously. With the dorsal armature and the pronotal horn the pupa is able to apply considerable force in making its escape from the aborted achenes. Neither the pupa nor the adult cuts an emergence hole. Often the evacuated pupal shell is left protruding conspicuously from the point of exit. The duration of the pupal stage in midsummer was 5 to 9 days. One pupa was observed alive on June 22. Usually only one pupa was found per achene, but three have been found in a single achene.

One predator and three parasites were found affecting this seed midge—the insidious flower bug, *Orius insidiosus;* a wasp, *Platygaster* sp.; and two chalcids, *Torymus obscura* (Breland) and *Rileya* n. sp.

The species winters as a larva in atrophied achenes in trash, either on the dead stalk or on or in the soil. Clean cultivation and plowing after harvest or during the winter should effectively control the midge in cultivated crops.

NOTES ON THE PREDATORS.—One adult of the insidious flower bug, *Orius insidiosus* (Say), was offered a cluster of 133 eggs of the sunflower-seed midge. In 1.5 minutes the bug punctured one egg in five places and finished the egg. It ran away from the eggs, then back, and swiftly emptied four eggs in the first 5 minutes. After 16.5 hours this one bug had destroyed the remaining 128 eggs.

The clerid beetle, *Hydnocera pubescens* Lec., is a predator in both the adult and larval stages. The species was present in budworm-infested sunflower and Jerusalem artichoke plants collected throughout the St. Louis area from July to October. There seems to be only one generation a year, and the larva appears to be the overwintering form. Though many larvae were collected on August 31, none spun their cocoons before February. Pupation continued into May, and adults issued successfully to June. Larvae of this beetle were observed preying on larvae and pupae of the sunflower budworm and the sunflower moth, *Homoeosoma electellum* Hulst, and on larvae of the sunflower-head cutworm. Both larvae and adults fed on plant lice when other food was not supplied.

NOTES ON THE PARASITES.—The larvaevorid fly, *Lixophaga variabilis* Coq., is similar to the house fly, but much smaller. It seemed to be the most constant natural control of the sunflower budworm wherever the budworm was found. Specimens were reared from July 17 to October 31. At least 21 days elapsed between deposition of eggs and issuance of adults. The species probably has several generations a year, wintering as larvae or as pupae within their puparia. The larva leaves the host before forming the puparium, and in midsummer may require 3 to 12 days after leaving the host before becoming adult, and more time in cool weather. This parasite was reared also from the larva of the sunflower-head cutworm and *Anomis erosa* Hbn.

The larvaevorid fly, *Siphophyto floridensis* Towns., is widely distributed in the United States. It was reared only once from the sunflower budworm, though many times from the sunflower moth infesting sunflowers and once from *Olethreutes hebesana* Wlk. infesting *Iris germanica* L. As collections were made from mid-July to September 29, it is probable that there are two or more broods each year. The larva feeds within the body of the host larva, one to a host. When mature, the larva leaves the host and forms its puparium.

The period spent in the puparium may be less than 8 days or as long as over winter.

The sarcophagid fly, *Helicobia helicis* Towns., was reared from the cocoon of the sunflower budworm, from larvae of the sunflower-head cutworm and the armyworm, *Cirphis unipuncta* (Haw.), and from an adult *Cicindela* sp.

The false stable fly, *Muscina stabulans* (Fall), is distributed generally throughout the United States. The writer has taken four puparia from one pupal cell of the cocklebur billbug, and has reared it from pupa of the sunflower budworm, and from larva of the armyworm. Collections of this fly were made from June 7 on, and adults issued as late as November 19. This species is probably more frequently a saprophyte than a parasite. Neither oviposition, nor eggs nor larvae were observed.

Microbracon caulicola Gahan., a braconid parasite, is widely distributed in the Middle Atlantic States. It was reared from the larva of the budworm in sun-

flower, collected on June 27. The age of the plant indicated that the host eggs were deposited in June. By July 3, five parasite larvae had left the host and formed cocoons of fine silk. Five female adults issued on July 9. Adults in the field were taken from August 16 to September 1.

Microbracon mellitor (Say), a braconid parasite, is widely distributed in the United States. It was reared from larvae of the sunflower-head cutworm and the sunflower moth. Adults were taken in the open or reared from August 21 to September 14.

Another braconid, *Microbracon* sp., was reared from a sunflower budworm larva taken from Jerusalem artichoke in the St. Louis area on October 30. The adult issued November 10 to 12, under laboratory conditions. This specimen had formed its cocoon when found, suggesting the probability that it would have spent the winter as a larva in its cocoon. The cocoon was opaque, white, and very small.

The braconid, *Chelonus altitudinus* Vier., was reared from a larva of the sunflower-head cutworm taken from a flower head at Caruthersville, Missouri, on August 31, and from larvae of the sunflower moth taken from sunflowers in the St. Louis area and in southeast Missouri on numerous dates from July 19 to September 29. Adults were issuing in the field as late as September 17. One that issued on November 4 in the laboratory from a larva collected on September 29 was probably forced by artificial heat. This fact would indicate that the species over winters as a larva within the host.

No sunflower moth larva yielded more than one larva of *Chelonus altitudinus*. This larva left the body of the host and spun a white silken cocoon about 6 mm. long within the web of the host. The larva from the sunflower-head cutworm formed its cocoon close to the shriveled host remains. The pupa changes from white to blackish 2 or 3 days before the adult issues. Several larvae of the sunflower moth and of *Feltia subgothica* Haw. were exposed to adults of this parasite without inducing oviposition.

Apanteles epinotiae Vier., a braconid parasite, was taken frequently in southeastern Missouri as a parasite of the sunflower budworm, adults issuing from August 5 to September 14–20. The adult issuing September 14–20 was in the laboratory about 3 weeks. Perhaps it would have had time to begin a second brood to winter in the new host. There probably are at least two broods a year. The larva feeds within the host and emerges therefrom to form a cocoon about 4 mm. long. Usually only one larva emerges from a single host larva.

Pristomerus euryptychiae, an ichneumonid parasite of the sunflower budworm, was collected at New Madrid on July 27 and issued August 9–20, from a sunflower. The larva feeds within the host. When mature, it leaves the host and spins a silken cocoon about 6 mm. long. The period within the cocoon is less than 12 days.

Platygaster sp., a multiple parasite, was collected in four larvae of *Lasioptera murtfeldtiana* from sunflowers at New Madrid on August 24, 1927. Taken but once, there is no indication of broods. It winters in the larval stage within the body of the host larva. Kept indoors, some adults issued on March 30 from one host larva, and on April 29 from another. Larvae were observed in one or two other host larvae as late as April 14. Four adults developed in each of two host larvae, and seven larvae were observed in another. From one of the hosts, four parasite larvae issued before pupating, whereas in others the larvae spun cocoons within the host. In one host three cocoons had heads one way and one the reverse. The length of the life cycle was not determined.

Torymus obscura (Breland), a chalcid wasp, is a very abundant parasite of the sunflower-seed midge, and occurred wherever the midge was found. Definite rearings were from this one host only. There are probably two or more generations annually. No observations definitely suggested the length of life cycle or the wintering form. Adults were taken from July 19 to September 7.

Rileya n. sp., a chalcid parasite, was occasionally found attacking *Lasioptera murtfeldtiana* in a dahlia-flowered hybrid sunflower, but was much less common than *Torymus obscura*. It was reared frequently from other species of midges, *Asphondylia globulus* O. S. and *Trischormomyia bulla* (Felt), in sunflower and Jerusalem artichoke. The adult is a smooth, brownish wasp about 3.5 mm. long. It issued on July 31 from the larva

of the sunflower-seed midge. Several adults, collected on September 21 as parasites of other hosts, issued October 1 to November 3. The larvae are white and hairy. The pupa is nude.

SUMMARY.—Information gathered concerning these several sunflower pests may be briefly summarized as follows:

The cocklebur billbug, *Rhodobaenus tredecimpunctatus* (Ill.), is one brooded, and the adult leaves the host plant to winter in other shelter. Eggs are laid in feeding excavations in stalk or leaf, beginning late in May at St. Louis. The larva requires about 10 weeks to complete its growth. Pupation requires about 5 days. The false stable fly, *Muscina stabulans* (Fall.), was the only parasite reared. Elimination of wild host plants and trash are recommended for control of this billbug.

The sunflower budworm, *Suleima helianthana* (Riley), has two or more broods each year, the species appearing to over winter as mature larvae, reaching the adult state early in the spring. Eggs are laid in such position that the larvae enter especially the terminal or the more tender axillary buds. The larva matures in about 40 days and the pupa in about 6. One predator and eight parasites were observed as natural controls. As the species over winters in the larval stage, the destruction of trash should help in the control of this moth.

The sunflower-head cutworm, *Stibadium spumosum* Grt., has only one brood each year. The eggs are laid in the sunflower head. The larva matures in about 30 days. The pupa stage requires about 10 months and pupation takes place in the soil. One predator and four parasites were observed contributing to the control of this insect. Plowing after harvest and before winter should aid in the control of this cutworm.

The sunflower-seed midge, *Lasioptera murtfeldtiana* Felt, probably has two or more generations each year. It winters in the mature larval stage. Adults issued from over-wintered larvae on April 24, and as late as November 19 from sunflower heads of the current season. Eggs are laid in the head, especially in open florets, sometimes many to a floret. The larva enters the embryonic achene and feeds upon and destroys the germ. When ready to issue, the pupa forces itself through a crack. The infestation is difficult to observe, because no hole is cut and because the devitalized achenes are blown away with the chaff at harvest. One predator and three parasites were observed as natural controls.—6-10-48.

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Use of Powders on Clothing for Protection Against Chiggers[1]

H. F. CROSS[2] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Recent investigations on methods of protecting individuals from chigger mites (Trombiculiidae) have been carried out largely with compounds that are long-lasting when used to impregnate clothing and are not readily removed by laundering. The best results have been obtained by treating all the outer clothing with mite-killing materials (Bushland 1946), but the application of these materials around only the openings of the clothing has also been satisfactory (Madden *et al.* 1944). Most of the compounds are viscous liquids, which tend to soil clothing, and many of them damage synthetic fabrics. A number of solid materials are highly effective when applied to the clothing as solutions in volatile solvents. This report covers tests conducted at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine which demonstrate the efficacy of some of the better solid acaricides when they are applied as powders.

[1] This work was conducted under a transfer of funds from the Office of the Surgeon General, Department of the Army, and, in part, from the Bureau of Medicine and Surgery, Department of the Navy, to the Bureau of Entomology and Plant Quarantine. The authors are indebted to B. V. Travis and Carroll N. Smith for advice and suggestions.

[2] This paper was prepared jointly by H. F. Cross and Richard L. Fye.

MATERIALS AND METHODS.—Four materials—benzil, *p*-cresyl benzoate, diphenyl carbonate, and 2-thenyl salicylate—were each mixed with talc to obtain the desired concentration. In preliminary laboratory tests 6-inch squares of cotton twill were treated with 0.5 and 1 gram of powders containing 5 per cent of the acaricides, equivalent to dosages of 100 and 200 mg. of toxicant per square foot. Ten chiggers were placed on each treated square to determine how rapidly they became paralyzed (stopping time) and how far they traveled before they were immobilized. Some were removed from the treated squares after 10-minute exposure and were observed at frequent intervals for about 6 hours, to determine the number that recovered.

A 5-per cent powder of each of the four materials was next applied to the cuffs of herringbone-twill sleeves as 2- and 4-inch barriers. In the laboratory approximately 100 chiggers were placed on the arms of subjects wearing the treated sleeves and the number of attachments noted after 3 hours. Other sleeves were treated around the cuff with 2-inch barriers of a powder containing 3 per cent of benzil, *p*-cresyl benzoate, or diphenyl carbonate and tested in the field.

Two series of tests were made on uniforms treated with powder barriers. In the first series powders containing 6 per cent of benzil, 2-thenyl salicylate, or diphenyl carbonate were each applied as 2- and 4-inch barriers around all openings of the clothing. About 10 grams of powder was required for the 2-inch, and 20 grams for the 4-inch barrier. The powders were also dusted lightly on the arms and legs of the subjects. In the second series powders containing either 5 or 10 per cent of benzil or diphenyl carbonate were applied in a band 4 inches wide around all openings of the clothing, and also dusted on the inner surfaces of the sleeves up to the elbow and the trouser legs up to the knee. From 30 to 40 grams of powder was used on each uniform. In both series the clothing was worn 8 hours a day for 3 consecutive days, including a daily exposure for 1 hour in an infested area in the field. After the third day the uniforms were washed in an electric washing machine for 10 minutes in warm water (118°–120° F.) containing 0.7 per cent of soap. They were rinsed twice in tap water and retested after they had dried.

In the final tests the entire inner surface of each uniform was dusted with a powder containing 5 per cent of the toxicant. Three uniforms were treated with 100 grams (approximately 4 grams per square foot) each of freshly prepared benzil or diphenyl carbonate powder, two with 100 grams of benzil powder that had been stored in containers for 165 days, and two with 33 grams of freshly prepared benzil powder. The uniforms were worn for 8 hours daily, including a daily exposure for 1 hour in areas of high chigger populations in the field. Two uniforms were treated with approximately 8 grams of 5 percent benzil powder, blown with a dust gun into the sleeves, legs, collar, and waist. These uniforms were tested immediately after treatment and after 1 day of wear.

In the field tests subjects wearing treated and untreated clothing were exposed to chiggers for 1 hour by walking, lying, sitting, and placing the hands on

Table 1.—Effect of 5 per cent powders containing various acaricides on chiggers exposed on treated cloth samples. (Average of 3 laboratory tests with 10 chiggers per test.)

ACARICIDE	DOSAGE (GRAMS)	MEAN STOPPING TIME (MINUTES)	DISTANCE TRAVELED (INCHES)	SURVIVAL AFTER 10 MINUTES (PER CENT)
Benzil	0.5	11	0.25–1.0	0
	1	7	.25– .50	0
Benzoic acid, *p*-cresyl ester (*p*-cresyl benzoate)	.5	12	.25–2	0
	1	8	.25– .75	0
Carbonic acid, diphenyl ester (diphenyl carbonate)	.5	3	.06–1	73
	1	2	0	0
Salicyclic acid, 2-thenyl ester (2-thenyl salicylate)	.5	6	.25–1.5	17
	1	3	.25– .75	0

the ground in areas where chiggers were exceptionally abundant. After an additional 2-hour waiting period the chigger attachments were counted and the difference in the numbers on subjects wearing treated and untreated clothing was used to estimate the effectiveness of the treatment.

RESULTS.—*Laboratory Tests.*—In the laboratory tests the stopping time and the distance traveled were less for chiggers exposed to diphenyl carbonate than for those exposed to the other materials (Table 1). With all four materials the stopping times and the distances traveled were greater at the 0.5-gram than at the 1-gram dosage. At the higher dosage there was no recovery from any of the materials, but at the lower dosage diphenyl carbonate and 2-thenyl salicylate allowed some recovery.

In the tests with sleeves treated at the cuffs with barriers of 5 per cent powders, benzil gave the best protection, and a 4-inch barrier was more effective than one 2 inches wide. Table 2 shows the results.

Table 2.—Chigger attachments with various treatments.

ACARICIDE	ATTACHMENTS	
	2-Inch Barrier	4-Inch Barrier
Benzil	1	0
Benzoic acid, *p*-cresyl ester (*p*-cresyl benzoate)	21	0
Carbonic acid, diphenyl ester (diphenyl carbonate)	3	1
Salicylic acid, 2-thenyl ester (2-thenyl salicylate)	5	7
Untreated sleeve (average of 8 nonconcurrent tests)	40	

FIELD TESTS.—In the field tests with sleeves treated with 2-inch barriers of 3 per cent powders, only benzil gave complete protection. *p*-Cresyl benzoate and diphenyl carbonate gave less than 50 per cent protection. 2-Thenyl salicylate was not tested.

In the tests in which the arms and legs of the test subjects were dusted and barriers were applied around all openings of the clothing, 6 per cent powders of benzil, diphenyl carbonate, and *p*-cresyl benzoate gave an average protection for 3 consecutive days of 95 to 99 per cent with 2-inch barriers and 99 to 100 per cent with 4-inch barriers. Similar tests with wider barriers of powders containing 5 and 10 per cent of benzil and diphenyl carbonate gave complete protection for 3 consecutive days. None of the uniforms gave as much as 85 per cent protection when tested after a washing following 3 days of wear. The individuals wearing untreated uniforms during the four tests had 187, 300, 277, and 254 chigger attachments.

Uniforms treated over the entire inner surface with 100 grams of 5 per cent benzil powder afforded better than 95 per cent protection for 7 days (Table 2). The powder was as effective after 165 days of aging as when freshly prepared.

Table 2.—Protection from chiggers afforded by uniforms treated over the entire inner surface with different dosages of powders containing 5 per cent of various acaricides. (Field tests.)

ACARICIDE	DAYS OF WEAR	ATTACHMENTS	PROTECTION
100 grams per uniform			*per cent*
Benzil, freshly prepared (3 uniforms)	0	0	100
	1	0	100
	2	1.7	98
	3	1	99
	4	0	100
	5	1.3	99
	6	.7	99
	7	.3	99
	10	13	93
Benzil, stored 165 days before treatment (2 uniforms)	1	.5	99
	2	0	100
	3	0	100
	4	0	100
	5	0	100
	6	.5	99
	7	2.5	99
Diphenyl carbonate, freshly prepared (3 uniforms)	0	0	100
	1	7	99
	2	12	95
	3	21	91
	4	22	62
33 grams per uniform			
Benzil, freshly prepared (2 uniforms)	0	0	100
	1	0	100
	2	0	100
	3	0	100
	4	1	99
	5	3	96
	6	7	93
	7	6	50
8 grams per uniform			
Benzil, freshly prepared (2 uniforms)	0	5[1]	99
	1	3	99

[1] Subject used as a check in this test had 785 chigger attachments.

Uniforms treated with 5 per cent diphenyl carbonate at the same dosage gave less than 95 per cent protection after the second day of wear. Uniforms treated with 33 grams of 5 per cent benzil powder afforded better than 95 per cent protection through 5 days of wear. Eight grams of benzil powder blown into uniforms while they were being worn was 99 per cent effective immediately after treatment and also after 1 day of wear. Subjects wearing the untreated uniforms in these tests had an average of 198 chigger attachments.

No pharmacological tests have been conducted with these powders, but all the compounds have been tested on rabbits by the Division of Pharmacology, U. S. Food and Drug Administration, either as skin applications or applied to cloth at dosages of 2, 4, and 8 grams per square foot. The tests indicated that 2-thenyl salicylate is safe for use on the skin, that benzil is suitable for use with caution on clothing at 2 grams, and that the other compounds are safe for use on clothing at 8 grams.

DISCUSSION.—Tests with acaricides applied as powders show that heavy dosages afford satisfactory protection for a week, and at a very light dosage for at least 1 day. The powders are easily applied by an individual and do not affect clothing containing synthetic fibers. Although powders are less durable than impregnations with volatile solvents or emulsions (Cross & Snyder 1948), they appear practical for those who wish protection for only a few days or are willing to re-treat the clothing after each laundering. The liquid impregnations are preferred if a long-lasting effect is desired or if clothing for large groups of men is to be treated.

SUMMARY.—Benzil, *p*-cresyl benzoate, diphenyl carbonate, and 2-thenyl salicylate, applied to cloth as 5 per cent powders caused paralysis of chigger mites (Trombiculiidae) in 2 to 12 minutes. In laboratory tests chiggers were completely paralyzed after crawling a maximum distance of 2 inches on treated cloth. Some of them recovered after exposure to light dosages of diphenyl carbonate and 2-thenyl salicylate.

In field tests powders containing 5 per cent of benzil, diphenyl carbonate, or *p*-cresyl benzoate applied to the arms and legs of the subjects and around openings to the clothing was 95 to 100 per cent effective in protecting persons from chigger attachments for 3 days. Uniforms dusted with 8, 33, and 100 grams of a 5 per cent benzil powder gave 95 to 100 per cent protection after being worn 1, 5, and 7 days, respectively. Of the four materials tested, benzil was the most effective. Treatments with powders are less durable than those with solutions or emulsions, but afford a high degree of protection for a few days, and can easily be applied without special equipment. Powder applications are well suited to the needs of the individual exposed occasionally to chiggers.—7-10-48.

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Control of the Cotton Fleahopper by Chlorinated Camphene, DDT and Sulphur

C. R. Parencia, Jr., and K. P. Ewing, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1,2]

In Texas, especially in the southern portion of the state, the cotton fleahopper, *Psallus seriatus* (Reut.), is a major pest of cotton practically every year. For many years sulfur and a mixture of one part of calcium arsenate and two parts of sulfur have been used for fleahopper control.

Sulfur is very slow in killing fleahoppers and is effective mostly against the nymphal stage; therefore, from two to five or more applications are usually required to give seasonal control. The mixture of calcium arsenate and sulfur is slightly faster in its killing action, kills a higher percentage of adults, and has the added advantage of killing boll weevils as well.

Field experiments conducted in 1944 and 1945 (Ewing & Parencia 1945) (Parencia *et al.* 1946) showed that DDT gave a much quicker and greater total kill of the fleahopper than either sulfur alone or the mixture of sulfur and calcium arsenate. Since 1946 a dust containing 5 per cent of DDT and 75 per cent of sulfur has been recommended for fleahopper control, and this mixture has been successfully used by many cotton growers in the last two years. In 1947 several million pounds of this dust were used in Texas alone. Usually two applications, made a week or 10 days apart, have given satisfactory control, even of extremely heavy infestations (100 to 200 fleahoppers per 100 terminals). The dust kills so quickly that the application does not have to be repeated in case of rain.

Dusting for fleahopper control is usually done early in the season, beginning about the time the first squares (buds) appear. In many fields boll weevils, *Anthonomus grandis* Boh., also occur in potentially injurious numbers and should be controlled. DDT does not control the boll weevil, and increased infestations of the cotton aphid, *Aphis gossypii* Glov., often follow its use. What is needed, especially in many large cotton-growing areas of Texas, is an insecticide that will be as effective as DDT against the fleahopper and at the same time will control other injurious insects that might be present, particularly the boll weevil.

In field experiments at Waco, Tex., in 1946 (Ivy *et al.*, 1947) chlorinated camphene (67 to 69 per cent of chlorine) gave promising results against the boll weevil, the cotton aphid, the bollworm, *Heliothis armigera* (Hbn.), and the cotton leafworm, *Alabama argillacea* (Hbn.). Cage tests indicated that this material would be effective against the cotton fleahopper, but no field tests were conducted against this insect. Therefore, field experiments were conducted in 1947 to determine which concentration of chlorinated camphene would give fleahopper control equal to that of DDT. One small-plot and six large-scale experiments were conducted in the upper coastal area of Texas, near Port Lavaca (Calhoun County), where fleahopper infestations ranged from light to extremely heavy, the peak in one experiment reaching 168 fleahoppers per 100 terminals. One large-scale experiment was conducted in central Texas, near Waco, where the infestation was medium to heavy. In these experiments five concentrations, ranging from 1.25 to 20 per cent, of chlorinated camphene were compared with the 5 per cent DDT-sulfur.

The plots in the small-plot experiment were 12 rows wide, 0.14 acre in size, and arranged in randomized blocks with 4 replications of each treatment. The plots in the large-scale experiments ranged in size from 2 to 15 acres, the untreated check plots averaging 3 acres and the dusted plots 8 acres. There were 2 replications of each treatment in each of the large-scale experiments at Port Lavaca, the replications being in different fields. At Waco the treatments were not replicated. The small plots were dusted with rotary hand dust guns and the large plots with power-take-off 8-row tractor-attachment dusting machines. The procedure and method of recording data were the same as have been previously reported (Ewing & Parencia 1943). The rates of application of the various treatments were ap-

[1] In cooperation with the Texas Agricultural Experiment Station.

[2] The authors wish to acknowledge the helpful assistance given by Williard N. Kettler in supervising the experiments at Port Lavaca and in making many of the routine field-plot records.

proximately equal in the same experiment. Boll weevils, bollworms, cotton aphids, and red spider mites did not become sufficiently numerous to cause appreciable damage in any of the experiments; however, the total damage caused by some of these pests might have affected the yields.

The chlorinated camphene used in the small-plot experiment was a commercial dust concentrate containing 40 per cent of chlorinated camphene in a clay product (Attaclay). The lower concentrations were prepared by mixing this dust concentrate with pyrophyllite at the Waco laboratory. For the large-scale experiments a commercial dust containing 20 per cent of chlorinated camphene, 30 per cent of clay, and 50 per cent of pyrophyllite was used. Pyrophyllite or sulfur was added to make more dilute dusts. The DDT-sulfur mixture was a commercial dust. The sulfur used alone and in the mixtures prepared at the Waco laboratory was a commercial dust of 97 per cent purity.

SMALL-PLOT EXPERIMENT.—The small plots at Port Lavaca were dusted on June 3, 7, 17 and 26. On the day before the first application the average number of fleahoppers per 100 terminals was 63. Twenty-four hours after the first dust application the infestation was reduced 91 per cent by the 10 per cent chlorinated camphene, 82 per cent by the 5 per cent chlorinated camphene, and 66 per cent by

Table 1.—Comparative effectiveness of chlorinated camphene, DDT, and sulfur against the cotton fleahopper in field-plot experiments[1] conducted at Port Lavaca, Tex., unless otherwise indicated.

Treatment	Rate of Application per Acre	Fleahoppers per 100 Terminals			Yield of Seed Cotton per Acre	
		Before Dusting	Reduction After 24 Hours	Seasonal Average	Total	Gain Over Check
	Pounds	*Number*	*Per Cent*	*Number*	*Pounds*	*Pounds*
Small-plot experiment						
Chlorinated camphene:						
10%	12	57	91	13	917	29
5%	13	70	82	16	1006	118
2.5%	13	59	59	22	960	72
1.25%	13	68	61	26	937	49
DDT 5% plus sulfur 75%	13	61	66	13	959	71
Untreated check	—	63	2	45	888	—
Difference required for significance, 5% level	—	—	—	8	59	—
Large-scale experiments 1 and 2						
Chlorinated camphene:						
20%	12	24	100[2]	4	1044	296
10%	10	46	100[2]	7	1023	275
DDT 5% plus sulfur 75%	13	35	97[2]	5	936	188
Untreated check	—	30	72[2]	17	748	—
Large-scale experiments 3 and 4						
Chlorinated camphene:						
10%	10	28	95	7	845	101
10% plus sulfur 50%	10	34	95	8	844	100
DDT 5% plus sulfur 75%	12	32	95	6	802	58
Untreated check	—	24	35	17	744	—
Large-scale experiments 5 and 6						
Chlorinated camphene:						
5%	12	88	93	11	904	22
5% plus sulfur 75%	13	82	87	13	828	−54
DDT 5% plus sulfur 75%	14	124	96	7	928	46
Untreated check	—	72	−6	54	882	—
Large-scale experiment 7 at Waco						
Chlorinated camphene:						
20%	11	49	97	8	683	275
10%	10	49	95	12	680	272
Sulfur	15	60	21	33	529	121
Untreated check	—	—	—	44	408	—

[1] Dates of application: Small-plot experiment, June 3, 7, 17, and 26; large-scale experiments (1) on May 23 and June 2; (2) June 4; (3) June 5; (4) June 4 and 14; (5) June 6 and 16; (6) June 10, 18, and 30; (7) June 19, 26, and July 3.
[2] Experiment 2 only.

the 5 per cent DDT-sulfur. Owing to the small size of the plots there was a continuous migration of fleahoppers from undusted plots into various treated plots which made it necessary to dust four times. Fewer applications were needed in the large-scale experiments. The infestation in the check plots reached a maximum of 117 fleahoppers per 100 terminals on June 6. The treatments and experimental data are shown in table 1.

Each insecticide reduced the infestation significantly below that of the check, and the infestations in the tests with low concentrations of chlorinated camphene (2.5 and 1.25 per cent) were significantly higher than those in the tests with 10 per cent chlorinated camphene and 5 per cent DDT-sulfur. In the untreated check the boll weevil infestation averaged only 3 per cent and the maximum aphid infestation was 0.02 aphid per square inch. The 5 and 2.5 per cent chlorinated camphene and the 5 per cent DDT-sulfur gave significant increases in yield over the untreated check, with no significant difference between these three treatments. The low yield with the 10 per cent chlorinated camphene treatment was due to some unknown factor and not to any lack of fleahopper control.

LARGE-SCALE EXPERIMENTS.—Treatments and experimental data for the large-scale experiments conducted at Port Lavaca are shown in table 1. Rains occurred within 24 hours after two of the applications were made, but immediate inspections showed that the dusts were effective in spite of the rains. Inspections made approximately 24 hours after the first applications showed that chlorinated camphene was equally as effective as the DDT dust in giving a quick kill of the fleahopper. The 10 and 20 per cent concentrations of chlorinated camphene were slightly more effective and the 5 per cent concentration slightly less effective than the 5 per cent DDT, and all dusts caused mortalities ranging from 87 to 100 per cent. Infestations in several untreated check plots were considerably reduced, owing to kill of the fleahoppers from the drift of dust across the check plots.

Although the 24-hour kill of fleahoppers was approximately as good from the 5 per cent chlorinated camphene as from the 5 per cent DDT, the residual effect was much better from the DDT. The residual control from 10 per cent chlorinated camphene was about equal to that from 5 per cent DDT, as is shown in the seasonal average infestation records (table 1) made at approximately 5- to 7-day intervals.

In experiments 3 to 6, inclusive, chlorinated camphene was used with and without sulfur. The dust without sulfur resulted in spotted increases in red spider mites which approached the damage point, but with sulfur present in the dust there were no noticeable increases in this cotton pest.

The loss in yield from the 5 per cent chlorinated camphene-sulfur treatment shown for experiments 5 and 6 was due to the effect of root rot on the cotton in experiment 5. In all other dusted plots increases in yield occurred. The gains from dusting for fleahopper control were considerably reduced, because continued dry weather caused excessive shedding of bolls and prevented maximum production of the cotton that had been protected from insects. In each instance the 10 per cent chlorinated camphene effected an increase in yield over the 5 per cent DDT. This increase was perhaps due to control of low infestations of other insects.

The treatments and experimental data for the large-scale experiment at Waco are also shown in table 1. The first application was washed off by a heavy rain in about 9 hours. In spite of the rain, infestation records made the following day showed 97 per cent kill of fleahoppers by 20 per cent chlorinated camphene and 95 per cent kill by 10 per cent chlorinated camphene, whereas sulfur alone showed a kill of only 21 per cent. The seasonal average infestation records showed excellent control of fleahoppers from 10 and 20 per cent chlorinated camphene and poor control from sulfur. There was a prolonged heavy migration of fleahoppers into the plots used in this experiment. From past experiences we may suppose that under such conditions at least five or six applications of sulfur alone at 5-day intervals would have been required for satisfactory fleahopper control.

Another interesting observation was made in this experiment. The original untreated check plot was on the north side of the test area and adjacent to the plot dusted with 10 per cent chlorinated camphene. During the first application there was considerable drift of the chlorinated

camphene into this 48-row check plot. Inspections 24 hours after the first application (which was washed off in 9 hours) showed 72 per cent reduction of fleahoppers in this check plot. Most, if not all, of this reduction was no doubt due to drift of the insecticide. Thereafter, an untreated plot on the south side of the test area, and adjacent to the sulfur plot, was utilized as the untreated check. The records for the untreated check in table 1, experiment 7, are from this area.

In spite of extremely hot, dry weather substantial increases in yield were obtained from the plots treated with chlorinated camphene. The cotton dusted with 20 per cent chlorinated camphene showed a gain, over the untreated cotton, of 67 per cent (275 pounds of seed cotton per acre), 10 per cent chlorinated camphene a gain of 67 per cent (272 pounds), and sulfur a gain of 30 per cent (121 pounds). Cotton in the plots dusted with chlorinated camphene began fruiting much quicker, and matured and was ready for harvest several weeks earlier than the cotton in the sulfur or untreated check plots.

SUMMARY.—Chlorinated camphene in concentrations ranging from 1.25 to 20 per cent were tested in comparison with DDT and sulfur in field-plot experiments against the cotton fleahopper, *Psallus seriatus* (Reut.), during 1947. Most of the plots were located in the upper coastal area of Texas near Port Lavaca, where fleahopper infestation ranged from light to extremely heavy. One experiment was conducted in central Texas, near Waco, where the infestation was medium to heavy.

Dusts containing less than 5 per cent of chlorinated camphene were found to be ineffective. Control 24 hours after treatment was approximately as good from 5 per cent chlorinated camphene as from 5 per cent DDT, but the residual effect of the DDT was much better. The residual control from 10 per cent chlorinated camphene was about equal to that from 5 per cent DDT.

In large-scale experiments at Port Lavaca gains in yield were greater from 10 per cent chlorinated camphene than from 5 per cent DDT. The greater increase from chlorinated camphene was probably due to control of low infestations of other insects.

At Waco cotton dusted with chlorinated camphene began fruiting much quicker, and matured and was ready for harvest several weeks earlier than cotton dusted with sulfur. The increase in yield over the check was 30 per cent from sulfur alone and 67 per cent from both 20 and 10 per cent chlorinated camphene.—5-25-48.

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Reduction of the Vegetative Growth of Alfalfa by Insects[1]

LOYD L. STITT,[2] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Alfalfa hay yields are noticeably reduced each year in southern Arizona and California during the period of high temperatures from late June to September. The plants are often stunted and unhealthy in appearance and frequently show yellowing. Many theories have been advanced for this seasonal period of retarded growth. The most common are high temperatures, the plants' need of a rest or dormant period, depletion of soil fertility, and, more recently, damage by insects (Carlson 1940, Jeppson & MacLeod 1946). The Bureau of Plant Industry Soils, and Agricultural Engineering, at Bard, California, has conducted investigations on the effect of different agronomic methods on the summer growth of alfalfa. According to the farm superintendent, certain procedures caused some improvement in growth, but they did not completely correct the condition. Investigations on the injury to the vegetative growth of alfalfa by insects were therefore undertaken by the Tempe, Arizona, laboratory of the Bureau of Entomology and Plant Quarantine.

The initial field-cage experiments to determine how much, if any, reduction in growth was caused by insects were made in 1941 on an alfalfa plot at the Bard Station; further tests were carried on in 1942.

EXPERIMENTS IN 1941.—The 1941 Experiments were made on alfalfa grown for hay, which was harvested in July, August, and September. Screen wire cages 3 by 3 by 3 feet were used. Throughout the growth of all three crops one cage was kept heavily stocked with insects that had been swept from the alfalfa in the same plot on which the cages were located, and one cage on the July crop and two on the August and September crops were kept free of insects. The first cages were established on June 30, plant-growth data were taken on July 22, and the hay crop was cut on July 23. To obtain information on insect injury to the hay crops harvested in late August and in September, cages were replaced over the same area as soon as each crop was harvested. Plant height and appearance of the three hay crops were used as measures of the injury caused by the insects. The alfalfa growing in the plot outside of the cages was similarly measured at the time data were obtained on the growth within the cages.

The plant heights for the alfalfa in the insect-free cages were as follows: July crop (one cage) 27.5 inches, August crop (two cages) 26.5 inches each, and September crop (two cages) 26 and 25 inches, the average height of alfalfa for the three crops being 26.3 inches. Alfalfa heights in the infested cage were as follows: July crop 14 inches, August crop 17 inches, and September crop 14 inches, or an average of 15 inches. Growth measurements of alfalfa near but outside the cages were as follows: July crop 18 inches, August crop 17 inches, and September crop 15.5 inches, or an average of 16.8 inches.

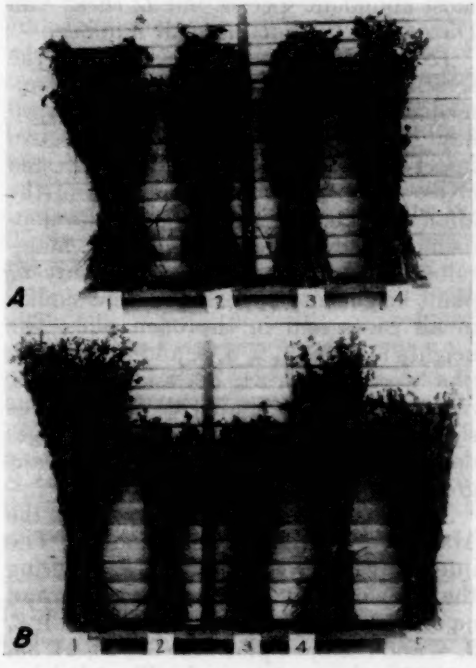

FIG. 1.—Hay from alfalfa grown in insect-damage experiments, 1942: 1 and 4, hay from insect free cages; 2 and 3, from infested cages; 5, from naturally infested uncaged plants. A, May crop; B, June crop.

[1] The writer expresses his appreciation to V. L. Wildermuth, under whose supervision these experiments were conducted, and to E. G. Noble of the U. S. Yuma Field Station, Bureau of Plant Industry, Soils, and Agricultural Engineering, Bard, Calif., for granting the use of alfalfa plots for the cage studies.

[2] Now with the State College of Washington, Western Washington Experiment Station, Puyallup.

Since plant heights and appearance in the infested cage and in the plot outside the cages were about the same in all three crops, it may be assumed that the insects in the infested cage caused about the same degree of injury as did those under field conditions. The difference between the average plant growth in the insect-free cages (26.3 inches) and in the infested cage (15.0 inches) indicates that insects greatly reduced the plant growth during the summer months. In the insect-free cages all three crops were similar in appearance. The plants were tall, healthy, and dark green, with large leaves, buds, and many-flowered panicles. The plants in the infested cages and in the uncaged portion of the plot were stunted and yellowish-green, with many of the leaves small and crinkled, buds damaged, and small, few-flowered panicles.

Populations of injurious insects per 100 sweeps of net in the uncaged portion of the plot were as follows: 4680 on July 15, 3000 on August 27, and 3080 on September 29. The most abundant insects were *Empoasca fabae* (Harr.), *Stictocephala festina* (Say), and *Lygus* spp. *Lygus hesperus* Knight and *L. oblineatus* (Say) were the most abundant species, but *L. elisus* Van Duzee was present in small numbers.

EXPERIMENTS IN 1942.—In 1942 the screen wire cages were put in place immediately after the harvest of the April hay crop. Four cages were used, two insect-free (Nos. 1 and 4) and two infested (Nos. 2 and 3). High populations of the alfalfa insects present during the development of the May hay crop were maintained in the infested cages. On May 27 plant height and appearance were similar in all cages and in the open plot. The heights in cages 1, 2, 3, 4, and in the open plot were 32, 31, 31, 32, and 31 inches, respectively. This similarity of height, as shown in the hay samples from these cages during May, did not seriously affect plant growth or appearance.

The cages were replaced as soon as the May hay crop had been removed. The infested cages were kept stocked during the development of the next crop, and on June 30 the plant heights in cages 1, 2, 3, 4, and the open plot were 31, 22, 24, 33, and 25 inches, respectively. Plant heights in the infested cages were thus decreased about 28 per cent and in the open plot 22 per cent. The plants in the insect-free cages appeared healthy, with large buds and flower panicles, and abundant flowers. The plants in the infested cages and in the open plot were somewhat stunted and yellowish in appearance, and insect injury of buds and flower heads was apparent. Differences in plant height of the hay samples for each treatment, and bud damage in the samples from the infested cages are shown in figure 1, B.

On May 27, when no definite reduction in plant growth was observed (Fig. 1 A), the population of harmful insects was 236 per 100 sweeps, whereas on June 30 there were 1408 per 100 sweeps and plant growth was materially reduced (Fig. 1 B). The populations of the different harmful insects found in the alfalfa on May 27 and June 30, just prior to the harvesting of the hay crops, are shown in table 1. The inference from these studies is that *Lygus* spp. and *Empoasca fabae* were probably largely responsible for the decreased alfalfa growth, because the increase of these species largely accounted for the increase of harmful insects. The results obtained in this experiment, which substantiate those obtained in 1941, indicate that insects reduced the vegetative growth. Results of similar experiments conducted by Ernest E. Russell, Bureau of Entomology and Plant Quarantine, at Bard, California, and Mesa, Arizona, in 1942 were in substantial agreement with those reported in this paper.

A cage experiment with the individual species suspected of greatly reducing the summer growth—namely, *Lygus* spp., *Empoasca fabae*, *Creontiades femoralis*, and *Stictocephala festina*—was also conducted at Bard during the summer of 1942. Ten cages were used. Five of these each contained 10 specimens and 5 each

Table 1.—Numbers of harmful insects found per 100 sweeps of net in a plot of alfalfa, 1942.

INSECTS	MAY 27	JUNE 30
Lygus spp.	16	200
Stictocephala festina (Say)	104	112
Empoasca fabae (Harr.)	38	948
Colias eurytheme Boisd.	0	8
Grasshoppers	6	8
Leafhoppers	10	32
Creontiades femoralis Van D.	16	4
Heliothis armigera (Hbn.)	2	8
Miscellaneous	44	88
Total	236	1408

Table 2.—Plant height in relation to insect feeding on caged and uncaged alfalfa plants in a field plot, 1942.

Insect	Mean Height at Harvest		Decrease Due to Insect Feeding	
	25 Insects per Cage	10 Insects per Cage	25 Insects per Cage	10 Insects per Cage
	Inches	*Inches*	*Per Cent*	*Per Cent*
Check (no insects)	16.2	19.6	—	—
Strictocephala festina	15.0	18.9	7.41	3.57
Creontiades femoralis	8.5	11.9	47.53	39.28
Lygus spp.	7.1	10.4	56.17	46.94
Empoasca fabae	4.4	9.0	72.84	54.08
Uncaged plants	9.3	8.9	42.59	54.59
Difference required for significance:				
At 5% level	3.37	2.98		
At 1% level	4.60	4.06		

contained 25 specimens of a single species. A check (insect-free) cage was used in each replication.

The cages were approximately 6 inches in diameter and 24 or 30 inches tall. A bottomless 1-pound coffee can was used for a base, and three wire uprights with a wire ring at the top were used for a frame. The frame was covered with a cheesecloth sleeve, the bottom of which was fastened tightly around the can and the top was tied so that it could be opened for inserting insects or making observations.

Cages were placed over individual plants as soon as the basal shoot had begun to grow. The desired number (10 or 25) of each insect species were placed in the cage when the alfalfa plants were 2 to 4 inches tall. The cages were not restocked during the experiment. Reduction in plant growth caused by these insects was determined by comparing the plant heights in the different cages at the time when the alfalfa would normally be cut for hay with the height of the uncaged alfalfa surrounding each replicate. The mean heights and percentage reductions in growth caused by the feeding of the different insects are given in table 2.

Decreased plant growth caused by feeding of *Creontiades femoralis*, *Lygus* spp., and *Empoasca fabae* was highly significant at population levels of either 10 or 25 specimens per cage, when compared with plant growth in the insect-free check cages. *Stictocephala festina* did not decrease the growth significantly. Most of the uncaged plants were shorter than those in the cages infested with 10 specimens, an indication that the complex of insects in the field was doing more damage per plant than 10 caged insects of any of the species, except *Empoasca fabae*.

No thorough studies were made of measures for the control of the insects shown by these experiments to be injurious to the vegetative growth, but from general observations it appears that harvesting all the alfalfa in a community on approximately the same date would reduce the insect injury. In 1941 insect populations averaged 3.2 per sweep in an area where the complete acreage was harvested at about the same time, as compared with 30.8 insects per sweep where experimental plots were cut on different dates.

SUMMARY.—Field-cage experiments were conducted at Bard, California, in 1941 and 1942 to determine how much, if any, reduction in plant growth of alfalfa was caused by insects. In 1941 experiments were made on the July, August, and September crops and in 1942 on the May and June crops. For each crop a screen-wire cage was kept stocked with one or more species of the insects swept from the plot on which the cages were located. Observations were made on plant heights and appearance of the different hay crops in these cages, in insect-free cages, and in the area outside the cages. Results indicated that insects materially reduced the vegetative growth during the period from June to September. The most abundant insects in fields of reduced growth were *Empoasca fabae*, *Lygus* spp., and *Stictocephala festina*. When lots of 10 and 25 specimens of each of these species and of *Creontiades femoralis* were caged separately on individual plants, all except *S. festina* caused highly significant reductions in growth as compared with growth in the insect-free check cages.

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Influence of Insects on Alfalfa Seed Production in Iowa

CARL J. DRAKE, *Ames, Iowa*

Insects affect alfalfa (*Medicago sativa* L.) seed production in two wholly unlike ways: First, through the effects by feeding, either directly (mechanically) or indirectly (chemo-physiologically); and, second, by serving as pollinating agents. These two diverse influences are vastly more important than generally realized by growers.

In Iowa the first alfalfa crop is cut for hay and the second sometimes let stand for seed. Leafhoppers, plantbugs, grasshoppers and other harmful insects are just attaining destructive proportions about the time the first crop is harvested for hay. Also, many species of pollinating insects such as wild bees are most abundant during late July and August when the seed fields are in full bloom.

At the time the plants reach the fruiting period, alfalfa, like other seed crops, must be healthy and vigorous to bloom profusely and produce a commercial seed crop. Heavy seedsetting, then, depends greatly upon the presence of an adequate population of pollinating insects during the blooming period to insure tripping and cross-fertilization of the flowers. Pollinating insects are most active and most abundant in seed fields on warm, still, sunny days. And cold, rainy weather entirely checks the field activities of these pollinators.

To eliminate or reduce the effects of insect feeding on seed alfalfa, two treatments with DDT are needed in average years for protecting (1) young plants during the growing period, and (2) maturing plants during the fruiting and seed-formation period. As a result of two insecticidal treatments, spaced about 12 or 15 days apart, the vegetative growth of the seed crop is generally about as heavy and sometimes even heavier than that of the first crop harvested for hay.

The potato leafhopper, *Empoasca fabae* Harris, lygus bugs (largely *Lygus oblineatus* Say), alfalfa plantbugs, *Adelphocoris lineolatus* Goerze and *A. rapidus* Say, clover seed chalcid, *Bruchophagus gibbus* Boh., occur year after year in destructive numbers in alfalfa fields. In most parts of Iowa the potato leafhopper almost invariably causes heavy yield reduction to the second and third hay crops. The first crop for hay is cut before the leafhopper, after its spring migration into the state from the south has had time to breed up in great numbers. New seedings of alfalfa also show much injury (yellowing and stunting) in late summer and fall. The insidious work of leafhopper and plantbugs, as well as depredation of cutworms, webworms, thrips, aphids and other harmful insects must be taken into consideration in seed production. Plants partly defoliated and with many leaves yellowed and badly discolored from insect feeding are unhealthy, low in vigor and produce little seed, which is largely of poor grade. In severe drouth summers, such as 1947, the populations of such insects as leafhoppers and plantbugs are greatly reduced, and under such conditions one DDT treatment (pre bloom) is almost as effective as two applications.

DDT is used in the form of dusts or sprays and applied by means of a power duster or sprayer from the ground or by special equipment from an airplane. In either dusting or spraying, from air or ground, approximately 1.5 pounds of DDT are applied per acre in the first treatment and 2 pounds in the second application. The wettable 50 per cent DDT powder was used with ground equipment and a miscible concentrate in xylene from airplane. The second or prebloom treatment is made just as the first buds begin to unfold and show color. In this way the toxic insecticides are on the outer surface of unfolding flowers, and thus do not kill or interfere with the activities of the pollinating insects seeking the floral products from within the open blossoms. When grasshoppers are present in harmful numbers, the gamma isomer of benzene hexachloride, chlorinated camphene, or chlordan is included with DDT in the spray and dust formulas. One of these compounds, used at the strength recommended by the manufacturers, gives good grasshopper control. The heavier second treatment of DDT is designed to protect the plants during the flowering and seed-forming period.

POLLINATING INSECTS.—Alfalfa is largely dependent upon the activities of insect agents for pollination. And as bees are the primary agents in bringing about fertilization, these insects must be present in large enough numbers to trip and cross-pollinate the flowers during the normal blooming period for a heavy seed set.

Associated with alfalfa blossoms are many species of insects that may conceivably be linked to some extent with pollination. However, only a small percentage of the many flower-visiting insects seeking pollen or nectar are of major importance in alfalfa pollination. Leaf-cutting bees, bumblebees and certain other wild bees are fast, active and very effective trippers and cross-pollinators. The primary species concerned in pollination often varies considerably in both numbers and species from one area to another.

Some of the smaller wild bees are weak or poor trippers, and not very successful in their tripping efforts, and pick up much pollen left by the larger bees. They also gather pollen from self-tripped flowers and those tripped by wind, rain, temperature changes and other causes. Although these bees might, to some extent, be called pollen-scavengers, they play a role of some importance in the cross-pollination of alfalfa in seed production.

The ability of wild bees to trip alfalfa blossoms varies greatly among different species, and somewhat between individuals of the same species and sex. Bumblebees, leaf-cutting bees and some other solitary bees are the most effective of wild bees, and one of these bees often trips from 12 to 30 times as many alfalfa blossoms per minute as a honeybee. Bumblebees work at lower temperatures than leaf-cutting bees and thus tend to put in longer hours per day.

The strong tendency of the domestic honeybee and many species of wild bees to visit flowers only or largely of one knd during the course of a single field flight is most conducive to cross-pollination of alfalfa, as well as of other plants. Likewise, the habit of visiting only a few flowers of a raceme before shifting to another plant is also very helpful. The question is often raised about the availability of pollen for cross-pollination, when such insects as bumblebees and honeybees carry pollen in moist masses on their hind legs, or on the under side of the abdomen as in megachilids. Field observations indicate that it is largely the loose pollen grains adhering to the fore parts of the body that actually come in contact with receptive organs of the flower when the insect enters the corolla.

Unfavorable weather, such as windy or cloudy days and very low or very high temperatures, greatly decreases the foraging activities and efficiency of pollen and nectar gathering insects. The population of wild bees in blooming fields is low when weather conditions are unfavorable for their field flights. Warm, still, sunny days (during the flowering period of seed alfalfa) have a vital bearing on bee-activity as related to seed setting.

The present records on tripping and pollination were taken during August and September of 1946 and 1947, in four alfalfa seed fields within a radius of 4 miles of Ames, Iowa. The wild bees were determined by Mr. Karl V. Krombein, and the flies by C. T. Green and C. W. Sabrosky, all of the U. S. National Museum. The tripping records were taken on warm, sunny, still days when the alfalfa plants were in full bloom. During such periods the honeybee and some of the smaller wild bees were more successful in tripping blossoms than before or after the main blooming period. The insects listed below were collected while actually tripping alfalfa flowers in one of the experimental fields.

Wild bees, particularly bumblebees and leaf-cutting bees, have long been associated with tripping of alfalfa blossoms and considered highly important in seed production. Very little is known about flower preference, nesting and habitat requirements, ecology and coactions of the various species of wild bees seeking the floral products. Interspecific strife, relationship and competition also have a bearing on the wild bee carrying capacity of an area or region.

Published data and conclusions of workers vary greatly relative to the value of the honeybee in alfalfa seed production. In most reports the honeybee is considered an inefficient tripper, and often takes the nectar without tripping and pollinating the blossoms. This has been a fertile source of confusion among workers. And the answer is not easily recognizable.

Species of Insect Pollinators of Alfalfa

Apidae

Anthophora walshii Cresson
Florilegus condignus (Cresson)
Apis mellifera Linneaus
Melissodes obliqua Say.
M. cnici Robt.
Bombus auricomus (Robt.)
B. impatiens (Cresson)
B. americanorum (Fabr.)
B. ternarius Say.
B. fervidus (Fabr.)
B. griseocollis (DeGeer)
B. vagana Smith
B. bimaculatus Cresson

Halictidae

Halictus parallelus Say
Lasioglossum forbesii (Robt.)
Agapostemon virescens (Fabr.)

Andrenidae

Agapostemon texamus Cresson

Megachilidae

Calliopsis andreniformis Sm.
Megachile latimanus Say
M. brevis Say
M. mendica Cresson
M. centuncularis (Linn.)

Coleoptera

Chauliognathus pennsylvanicus DeG.

The interrelations between wild bees themselves and between honeybees and wild bees are exceedingly complex and variable. Intolerance of the bees themselves towards too much crowding during the blooming probably enters into the equation under special conditions. Salt (1940), Peck & Bolton (1946) and others state that honeybee densities may be indirectly responsible for a reduction in the number of wild bees in alfalfa. This conclusion is based on the fact that the removal of nectar from alfalfa bloom leaves the flowers less attractive to wild bees that are more capable of tripping and cross-pollinating the flowers. These conditions, of course, would occur during weather unfavorable for nectar secretion, before and after the main bloom and when the honeybee population density is very large. Observations in Iowa indicate that moderate populations of honeybees are helpful because they cross-pollinate self-tripped flowers (also those tripped from other causes) and trip and pollinate a small percentage of flowers themselves.

As virtually nothing is known of interspecific relationship among wild bees and between them and honeybees, the conclusions will remain problematical until research data lend themselves to scientifically acceptable analysis. Wild bee populations are self-limiting and self-adjusting and can be materially increased by careful management.

Unless otherwise stated, the flower tripping records of bees are based entirely upon the activities of females. In the coures of a single field flight, many bees not infrequently visit racemes where some blossoms have just been tripped by other insects and from other causes. In following the flight paths of bumblebees and honeybees gathering their floral loads, it was observed that an individual bee occasionally returns to a raceme, which it had previously visited only a few minutes before. Also, bees sometimes visit "open-tripped" blossoms, especially some of the smaller and poorer tripping species.

The above observations show how some errors at times may unavoidably be made in taking the tripping records of individual bees. Freshly self-tripped or mechanically tripped flowers have lost no floral offering and are attractive to nectar- and pollen-gathering insects. Some bees are rather shy, easily distrubed and work rapidly so that detailed movements of their mouth-parts cannot always be followed closely by the human eye.

After the sexual organs of the alfalfa flower have been released, the standard petal in a short time begins to show signs of wilting. According to Tisdale (1946) the standard petal soon begins to wrap around the sexual column of a tripped flower and the flower then takes on a wilted appearance after 30 minutes to 2 or 3 hours, depending upon temperature and other factors. In most cases the error in taking tripping records of individual insects is slight and probably not significant. The error is greater, however, in the case of poor trippers and of bees that tend to gather pollen freely from "open-tripped" flowers. According to preliminary experiments by Peck & Bolton (1946), alfalfa pollination with foreign pollen may be effected 1 hour (and possibly longer) after the blossoms have been tripped.

DISCUSSION OF SPECIES.—Leaf-Cutting Bees: Three species of leaf-cutting bees, *Megachile latimanus*, *M. brevis* and *M. mendica* were moderately common in alfalfa seed fields in 1947. *M. centricularis* was the commonest species in one of the alfalfa fields in 1946, but this leaf-cutting bee was not seen in this same field in 1947 until near the end of the blooming period. *M. brevis* did not entirely disappear in the fall of 1947 until after alfalfa and bull thistle, *Cirsuim lanceolatum* L., flowers were killed by freezing frosts in late October.

The blossoms of bull thistle, wild bergamot, *Monarda fistulosa* (L.) (Hill), and red clover are favorite sources of food for these megachilids. The three species could always be taken on bull thistle growing in fence rows adjoining the alfalfa seed fields.

Many observations were made on the tripping abilities of megachilids in alfalfa. These insects move rapidly from plant to plant, tripping from one to three and occasionally four or five flowers on every raceme visited. No racemes were found where they had failed to trip any flowers.

Megachile latimanus is the largest species of the three. In visiting 27 racemes it tripped 63 flowers, an average of 2.3 flowers per raceme. Its tripping rate is usually between 20 and 35 flowers per minute. However, one female tripped 48 flowers in one minute. *M. brevis* usually trips one or two flowers and occasionally three or four flowers per raceme. Another female was observed to trip 18 alfalfa blossoms in 32 seconds before transferring to the heads of red clover. The highest record for *M. brevis* was 42 flowers tripped in one minute.

BUMBLEBEES: *Bombus auricomus* and *B. impatiens* were the two commonest bumblebees encountered in the flowering alfalfa fields. The specimens were usually females and often heavily laden with pollen. Only a few specimens of the six other species listed above were taken on alfalfa blossoms. One male and one female of the inquiline *Psithysus variabilis* were taken while tripping alfalfa blossoms. Another pair of *P. variabilis* was collected on bull thistle.

Both *Bombus auricomus* and *B. impatiens* are good trippers and tripped almost every flower visited. An examination of 30 racemes visited by these two species of bumblebees showed freshly tripped flowers on every raceme.

On 21 racemes, taken at random, females of *Bombus auricomus* tripped a a total of 87 flowers, or an average of 4.1 flowers per raceme. In another field an examination of 32 racemes (each visited by a different female *B. auricomus*) showed 142 tripped flowers, an average of 4.6 blossoms per raceme. *B. impatiens* tripped a total of 267 blossoms while visiting 119 racemes, an average of slightly over two flowers per raceme. These two bumblebees visited from 7 to 16 racemes per minute. Unfavorable, windy weather adversely affects the tripping rate of bumblebees as well as of other bees.

HONEYBEE: *Apis mellifera* was always the dominant bee in the alfalfa seed field. The population averaged between 2 and 3 bees to as high as 5 and 6 bees per square yard in most fields during the main blooming period.

The honeybee, as a rule, is a poor tripper and succeeds in tripping flowers on only one raceme out of about every 7 or 8 visited. Randomized records taken of individual bees on 76 racemes showed 19 tripped flowers on 10 racemes, and 66 racemes without tripped blossoms. One of these 10 racemes had 6 flowers tripped. Another bee was checked consecutively for 25 racemes. It visited a total of 97 flowers, but tripped only five of them. On another occasion one bee was observed to trip a total of 11 flowers on 6 racemes; it then suddenly took flight and disappeared

During the space of about a half-hour, records were taken of 15 honeybees while they visited 32 racemes (2 racemes per bee). These bees worked a total of 156 open flowers and tripped 15 of them. Only 6 of the 16 bees during this period tripped flowers; of these, three bees tripped one flower each, one tripped 3, one 4, and the other 5. Very few of the honeybees were heavily laden with pollen although many were carrying some pollen.

The large population of the common honeybee day after day during the alfalfa blooming period helps to compensate to some extent for its poor and undependable tripping ability. Its value as a pollinator is also increased because it often cross-pollinates open-tripped flowers that have been tripped by various causes other than pollinating insects.

Moderate populations of honeybees do not seem to affect, at least noticeably, the number of visits or species of wild bees visiting alfalfa. As a rule, not more than one bee of the larger species, such as honeybee, bumblebee, or leaf-cutter bee, will be found at one time collecting pollen and nectar from a single raceme. As soon as this bee leaves, another bee of the same or different species may work flowers on this same raceme. Not all the open flowers of a raceme are worked during a single visitation. And as honeybees are poor trippers, the pollen from untripped blossoms remains undisturbed on the anthers. It is not uncommon to find several bees of the same or different species visiting different racemes at one time on an alfalfa plant, especially large plants.

During the process of collecting a load of floral secretions, the honeybee or bumblebee, as it wends its way from plant to plant, now and then suddenly shifts its course so as to avoid calling at racemes being worked by other bees. No fighting was observed between bees of the same or different species over alfalfa flowers. Observations were not made on the activities of the small wild bees in relation to honeybees or other bees.

On numerous occasions, fighting was observed between *Melissodes obliqua* and bumblebees over the flower heads of bull thistle. These bees strike swift and hard. The bee, which is busy gathering nectar and pollen from a thistle head, is hit hard in a dive from the air. The attacking bee suddenly swoops down, strikes the bee on the thistle flower and knocks it entirely off the flower head. The victim often drops a foot or two in the air before catching itself in flight. The movements are too fast for the eye to determine if the assailant used its sting. Bumblebees, leaf-cutter bees and some other wild bees are more aggressive and rougher than honeybees while working the open alfalfa flowers, which probably accounts to some extent for the marked differences in tripping abilities.

The following observations were mad on a small rectangular tract of 2 acres of Ranger alfalfa during the summers of 1946 and 1947. The tract was located in the southeast corner of a 20-acre cornfield (in corn both years). On the east side of the alfalfa, corn was grown in 1946 and oats in 1947. The field on the south side was in mixed timothy-legume pasture in 1946 and in corn the following year. The alfalfa sown in 1944 was good; three crops of hay were harvested from the tract in 1945. The second crop was let stand both years for seed. Two treatments, a dust mixture of 10 per cent DDT, one per cent gamma benzene hexachloride and 89 per cent talc were applied both years. Excellent control was secured, and insect injury was at a minimum. An apiary of 30 colonies of honeybees, about a half-mile from the alfalfa, provided an abundance of honeybees. Narrow, clean fence rows on the 160-acre farm made conditions unfavorable for many wild bees to breed and nest. Wild flower pasture for bees was very poor.

During the main alfalfa blooming period in 1946 the honeybee population averaged between 12 and 15 bees per square yard. The population of wild bees, especially bumblebees and leaf-cutter bees, was low, and no field-counts of different species were made. As a result of the scarcity of wild bees, tripping was poor, and the alfalfa flowers wilted slowly. Only 40 pounds of recleaned alfalfa seed were obtained from the 2 acres (1946), and there was an almost equal bulk of poor and badly shriveled seed in the cleanings.

From this same tract of alfalfa, 420 pounds of recleaned seed were obtained in 1947. The number of honeybees averaged between three and five individuals per square yard during the blooming period. The population of bumblebees and leaf-cutter bees was moderately large, and small wild bees were present in fair numbers. Tripping was good, and the flowers soon wilted. Twenty-one different species of wild bees were taken in this small tract in 10 days, bumblebees and megachilids being the commoner species. In walking slowly across the tract lengthwise (near the middle), 44 bumblebees and 31 megachilids were counted visiting flowers in a strip about 15 feet wide, between 8 and 9 o'clock A.M. on August 21, 1947; and 30 bumble bees and 15 megachilids between 9 and 10 o'clock. These were the largest counts secured during the blooming period. Weather conditions were unsually good for insect pollinators during the flowering period of both summers. Drought was rather severe during the late summer of 1947.

The above data are not conclusive, and

may apply only to small alfalfa tracts, under special or limited conditions. Such heavy populations of honeybees have not been observed in large fields, even near large aparies. Moderate populations of honeybees do not seem to interfere with the activities of wild bees, and are helpful in alfalfa seed production. As many factors and conditions enter into the seed production picture, further study is much needed. The evidence, however, tends to support some of the findings and questions raised by such careful workers as Salt (1940), Peck & Bolton (1946) and Lindsey (1946). Pearson's (1933) observations in Wisconsin may also be applicable here. Many combinations of factors enter into the ecologic arrangements of densities of mixed populations of wild bees, honeybees and other insects in alfalfa pollination. As stated elsewhere, it is important that the blooming of seed fields should take place when wild bees are most abundant. The time of flowering of a field can be controlled by carefully planning and staggering the cutting of first-crop for hay.

ANTHOPHORID BEES: *Anthophorus walshi* was seen collecting pollen from alfalfa on almost every field trip. It is rather shy, not common and rarely taken in sweeping nets. On one field trip, Sept. 6, 1947, more than 40 females were counted collecting pollen along one side of a late seed field of 30 acres in full bloom. This was the only time during the two seasons when this large bee was seen in moderate numbers. As a rule, only a few specimens were observed in a field. The female trips from one to four flowers per raceme, mostly one or two. The male was observed a few times on bull thistle but it was not seen on alfalfa or red cover blossoms.

One female of *Anthophorus walshi* tripped a total of 18 flowers on 10 consecutive racemes; another bee 15 flowers on 10 racemes. Numerous counts showed that this bee was tripping from 8 to 12 alfalfa flowers per minute. It was also taken many times on the blossoms of red clover, bull thistle and bergamot growing along a railroad track which bordered one side of a seed field.

SWEAT BEES: *Agapostemon virescens* Fabr. was observed tripping alfalfa flowers on several field trips. It usually trips two or three blossoms on a raceme before shifting to another plant. Numerous specimens were taken on the flowers of bull thistle and wild bergamot in fence rows bordering alfalfa seed fields. On Aug. 6, a female of *A. texanus* was collected after it had tripped two alfalfa flowers. This was the only observation on alfalfa.

Halictus parallelus Say often trips from one to three flowers on a raceme before winging its way to another plant. One female was carefully followed for 14 racemes; it tripped from one to three blossoms on each of the racemes. *Lacioglossum forbesii* was also taken while visiting the flowers of alfalfa. It was not common in fields under observation.

Halictids, especially the smaller species, are not always successful in their efforts to trip alfalfa blossoms. These bees often gather pollen from open-tripped blossoms, also pollen not removed by other bees. They are thus of some importance in the cross-fertilization of flowers tripped automatically, or by rain, wind and other environmental factors.

CANTHARID BEETLE: The soldier beetle *Chauliognathus pennsylvanicus* De Geer was the only beetle observed deliberately tripping alfalfa flowers. Its mouth-parts are elongated and specially modified for for gathering the floral offerings, which are eaten as removed from the blossoms. This beetle is slow, awkward and of times fails in its tripping efforts. Pollen from naturally self-tripped flowers or from those tripped by other means is also eaten. The dorsal and ventral surfaces of the head and the upper surface of the pronotum are usually fairly well plastered with pollen grains from contact with the released anthers. This beetle is more frequently caught in the tripping mechanisms than bees, and occasionally has some difficulty freeing itself.

Records for the beetle are counts made at random in four alfalfa seed fields during the main blooming periods. In working 65 racemes, the beetles tripped 64 flowers on 40 racemes and none on the other 25. On these racemes, the tripping records were none, one, two and only occasionally three or more blossoms.

This soldier beetle feeds on the floral products from morning till night. The long visiting hours compensate a little for its slowness. The population is small in most fields. As the beetles are sometimes not easily disturbed, farmers were much interested in watching them trip and work al-

falfa blossoms. The beetle is more successful in its tripping efforts than are many of the smaller bees. In one field of about 6 acres in 1946 the beetle population averaged between one and three beetles per square yard. This is the only time it was found in numbers in alfalfa seed fields. Both males and females visit flowers of many kinds of plants.

MISCELLANEOUS INSECTS: Flies, butterflies, moths and many other nectar and pollen feeding insects are always present in flowering alfalfa fields. Some attention was given to syrphids, wasps, and other flower-visiting insects. Grasshoppers, when they alight on, or take off from a raceme occasionally trip a few flowers with their legs, as do large wasps such as *Chlorion ichneumoneum.* (L.). Such tripping is purely mechanical and accidental. The alfalfa butterfly, *Colias eurytheme* (Bdv.), and other butterflies are often found in considerable numbers in blooming seed fields. It usually takes many observations to find a freshly tripped flower on a raceme where these butterflies or other Lepidoptera had been sipping nectar. A small skipper butterfly (Aug. 30, 1947) was observed to trip four flowers on five racemes (1, 2, 1, 0, 0 flowers per raceme); the insect then flew swiftly away, was lost, and the species was not determined.

Syrphid flies such as *Tubifera tenax* (L.), *T. flaripes* (Walk.), *T. latifrons* (Loew), *Helophilus* Loew, *Metasyrphus peplexus* (Osb.) and *Sphaerophoria cylindrica* (Say) are often found on open flowers and leaves but they were not observed to trip blossoms. *Winthemia sinuata* Rein. (Larvaeoridae), *Exoprosopa fasciata* (Macq.) (Bombiliidae) and other Diptera were often taken resting on alfalfa. Asilids seem to find alfalfa a favorite place to prey on other insects. Some of the larger species, as *Promachus rufipes* (F.), trip flowers accidentally with their legs, when they happen to alight on or take off from flowering racemes.

The sphecid wasp, *Anacrabro ocellatus* Packard, was collected on alfalfa leaves; its nests in sand are often provisioned with *Lygus oblineatus* Say. The conopid fly, *Zodion obliquefasciatum* Macq. was taken while resting on alfalfa plants. It is a parasite of adult bumblebees.

INCREASING EFFICIENCY OF WILD BEES. —Considerable attention needs to be given to methods for increasing the efficiency and numbers of pollinating insects. The carrying out of a carefully planned program, as discussed below, will have the same beneficial effect on seed setting as doubling or even trebling the local population of wild bees and hive bees.

Alfalfa pollination may be greatly increased by (1) locating seed fields adjacent to open timber, streams, and rough raw land which sites provide favorable nesting and foraging areas for wild bees; (2) staggering the cutting of the first crop for hay so as to double or even treble the length of the flowering period of seed fields (accomplished by dividing a field into two or three equal parts and then spacing the haying of each at intervals of 8 or 10 days apart); (3) avoiding the competition of sweet clover, red clover and other clovers by planning the haying ahead so that these crops will not be in bloom at the same time as the alfalfa seed fields; and (4) avoiding the competition of wild flowers. Ofttimes, it may be necessary to cut some wild flowers growing near alfalfa, if both should happen to be in full bloom at the same time. Some wild flowers are quite distractive, and are preferred by bees to alfalfa.

The longer flowering period of the seed fields (due to interval cutting of hay crop) is also very beneficial to both wild bees and honeybees.

The spreading of the blooming time of seed alfalfa is of prime importance in building up bee-activity and thus increasing seed setting. After having once started to work a favorite plant flower, many bees have a more or less strong tendency to continue foraging on this flower as long as new bloom provides ample floral secretions. This tendency in some wild bees and especially in the honeybee was evident in seed fields where interval cutting of the previous hay crop had greatly extended the length of the flowering period, and the longer floral pasture period keeps attracting more wild bees to alfalfa bloom. As a result of the increasing activity of pollinating insects, seed yields from the later blooming parts of the fields (second and third interval cuttings) were generally heavier than the earlier (first) cutting. And timing the interval haying also enables growers to have alfalfa seed fields in bloom when the more efficient pollinating insects are most abundant in late summer.

Commercial beekeepers located near seed fields properly treated with DDT, report high yields of alfalfa honey. No DDT injury was observed to honeybees or wild bees in the test fields, and many beekeepers are anxious to have alfalfa and clover seed fields treated for seed production. The same statement applies equally well to benzene hexachloride or other compounds included to kill grasshoppers. No attempt was made to measure the increase in nectar yield as a result of DDT treatments, or the benefit derived from the prolonged flowering

SEED YIELD.—The alfalfa seed yield is given after the seed from the combine has been recleaned for market. In experimental fields in central Iowa in 1947, the yield from the second crop ranged from 3.2 bushels to 4.53 bushels per acre. The highest field yield, 68 bushels from 15 acres, was obtained near Coon Rapids, Iowa. Practically all untreated alfalfa near the test fields was cut for hay because of the failure of plants to set pods. One untreated field near Coon Rapids yielded about a half-bushel per acre of clean seed.

Alfalfa fields, poorly and unevenly treated from the air by commercial companies, yielded from one-half to slightly more than one bushel per acre. Strips of alfalfa were often missed between flying swaths. In many cases, markers were not used to help the pilots secure complete coverage. The dust mixture consisted of 3 or 5 per cent DDT. Spraying or dusting from the air was satisfactory, when good coverage and proper amount and strength of DDT were used.

In contrast, the writer supervised the dusting of 15 acres of alfalfa from the air, and the field yielded at the rate of 3.2 bushels of recleaned seed per acre. Ten per cent DDT was used. Markers were employed at each end of the field to guide the pilot. The dust-mixture was applied early in the morning as the sun was coming up. The air was very still, and the plants were wet with dew. Coverage was excellent and no strips between swaths were missed.

Several farmers took two quick hay crops and then let the third growth stand for seed. Yield from third cuttings ranged from nearly 1 bushel to 3 bushels per acre. A farmer near Grimes harvested 15 bushels of cleaned seed from 5 acres, and another at Coon Rapids 21 bushels from 7 acres. Rain, snow and freezing weather often made it difficult to combine late fields, and in three cases the farmers were not able to harvest the seed crop until early January, 1948.

The highest alfalfa yields in field tests in 1947 were obtained by W. B. Hall in western Nebraska. From 250 acres, Hall hulled 2020 bushels of alfalfa seed. The best field, of 50 acres, yielded 500 bushels, or at the rate of 10 bushels per acre. The latter was the third crop, two crops having been cut for hay. In the other fields the second growth was let stand for seed. Hall and his son flew to Ames and the writer helped them work out a program of two treatments (ground powder dusting, using 10 per cent DDT). The cutting of the hay crop was staggered so as to prolong the flowering period of each seed field to 30 or 40 days and, in addition, 256 swarms of hive bees were moved from Texas to the Hall farm about the time the alfalfa bloom began to unfold. Approximately 7 tons of extracted alfalfa honey were harvested. Many examinations in the field during the honey-flow period failed to show any signs of injury to honeybees or wild bees.

SUMMARY.—Insects affect alfalfa seed production in two entirely unlike ways: (1) through the effects of feeding on young and fruiting plants and (2) by acting as pollinating insects. As only healthy, vigorous plants are capable of flowering profusely and producing a heavy seed crop, two treatments of 10 per cent DDT are recommended to control insect pests. When grasshoppers were present, benzene hexachloride or another poison was also included.

Efficiency of pollinating insects was doubled and even trebled by staggering the cutting of first-crop for hay (8 to 10 day intervals). In this way the flowering period of a field was prolonged from 10 to 20 or even 40 days, and this has about the same results on seed-yield as increasing two or four times the local population of wildbees. It is also good for the honeybee as demonstrated by honey yields.

Locating seed fields along rough raw land, streams and open timber is also helpful, because of the more favorable nesting and breeding sites. Pollinating bees depend upon wild flowers for food and provision for their nests.

A list of wild bees found tripping alfalfa flowers in the vicinity of Ames is given. Leaf-cutter bees and bumblebees were effective trippers and the most important pollinators. Several other species of wild bees tripped flowers, but they were not very common in alfalfa fields. The soldier beetle, *Cauliognathus pennsylvanicus*, was of minor importance, and was the only beetle observed actually tripping flowers for pollen.

The honeybee was the dominant bee in every alfalfa seed field. It often sips up the nectar without effecting tripping and cross-pollination. To some extent, its numbers compensated for its poor tripping ability. Credit should be given the honeybee and small wild bees for pollinating flowers tripped automatically and from causes other than insects.

Tripping abilities and rates per minute are given for several species of wild bees and honeybees. In general, a bumblebee or leaf-cutting bee trips from 12 to 30 times as many alfalfa blossoms per minute as the domestic honeybee. Leaf-cutter bees were observed to trip as high as 48 alfalfa flowers per minute, averaging from 20 to 35 flowers a minute. Moderate numbers of honeybees seemed very helpful in seed production. High yields depend upon the presence of such good trippers as bumblebees and megachilids.

In the experimental fields in central Iowa, alfalfa yields in 1947 ranged from 3.2 bushels to 4.5 bushels per acre of recleaned seed. The highest yield in an untreated field was 1 bushel of seed from the combine (about a half-bushel of cleaned seed).

The highest yields were secured by a farmer in western Nebraska. From 250 acres of alfalfa, 2020 bushels of clean seed were hulled; one field of 50 acres yielded 500 bushels, or at the rate of 10 bushels per acre. In the latter field, two quick crops were cut for hay and the third left for seed. The alfalfa seed fields were treated twice with DDT, and cutting of hay crops staggered so as to prolong the flowering time of each field.

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Dr. Frans Verdoorn, Managing Editor of Chronica Botanica, has been appointed Director of the Los Angeles State and County Arboretum at Arcadia, California.

Dr. Verdoorn will assume the directorship of this new arboretum in the immediate future. It is planned to develop a modern arboretum and botanical garden at Arcadia with various educational and research departments.

Dr. Verdoorn will continue to edit Chronica Botanica and related serials. Some of these will be published in the future by the Los Angeles State and County Arboretum, others will be transferred to a commercial publisher.

Factors Affecting Toxicity in Formulating Chlordan Emulsions[1]

YUN-PEI SUN, LELAND B. NORTON and W. A. RAWLINS, *Cornell University, Ithaca, N. Y.*

Various factors affecting the toxicity of chlordan,[2] 1, 2, 4, 5, 6, 7, 8, 8-octachloro-4, 7-methano-3_a, 4, 7, 7_a-tetrahydro-indan, in liquid formulations were studied using the melon aphid, *Aphis gossypii* Glov., as a test insect. Since each component in the formulation may contribute to the mortality of the sprayed aphids, only one component was varied at a time so that the importance of that component could be easily evaluated. Due to the complete miscibility of chlordan with many synthetic organic solvents as well as petroleum and vegetable oils no auxiliary solvents are needed in its formulation as is often required for DDT or benzene hexachloride.

METHOD.—Being completely miscible with kerosene, chlordan can be formulated in any proportion in an emulsion concentrate. However, it is important to choose an emulsifier which is oil soluble and completely miscible with chlordan and its solvent. The standard formulation used in the following experiments contained 20 g. chlordan, 77 ml. kerosene (or other solvents), and 10 ml. emulsifier A (see footnotes under table 3) (or other emulsifiers). For each spray, 10 ml. of this emulsion concentrate were diluted by pouring the concentrate into a small portion of water with constant stirring. Then the remaining of water was added and stirred for 5 to 10 minutes to ensure complete mixing before spraying.

When the emulsion was ready, a piece of squash leaf was cut off from a squash plant with a natural infestation of melon aphids, selecting each group of aphids so that the number of aphids and the proportion of various age groups would be as uniform as possible. This piece of leaf was pinned on a small board and sprayed using a constant speed conveyor type precision sprayer as described by Hansberry (Campbell and Moulton 1943). The leaf was flat on the conveyor 11 inches below the DeVilbiss spray gun, and a pressure of 15 pounds per square inch was used. It was found by sample weighings that after two passes over the conveyor, the deposit of a diluted emulsion was 4.5 mg. per square centimeter. This deposit was about the same for all treatments. After spraying, the pieces of leaf were transferred to individual biological specimen dishes which were stacked one on another after the sprays had dried. The living aphids were counted just before spraying and after 24 hours. Aphids showing movement on prodding were considered as living. The apparent mortality was first obtained as the difference between the numbers of living aphids before spraying and one day after treatment, and then the corrected per cent reduction of population was calculated according to the equation suggested by Sun and Shepard (1947).

EFFECT OF THE AMOUNT OF EMULSIFIER.—The standard formula used in this experiment consisted of 20 g. chlordan, 77 ml. kerosene, and 10 ml. emulsifier A[1]. At a dilution of 1:1000, the spray contained 0.01 volume per cent of emulsifier and the emulsion appeared stable. To the emulsion concentrate various amounts of the emulsifier were added so that the diluted sprays would contain 0.05, 0.1, 0.5, and 1.0 volume per cent of emulsifier while other constituents remained unchanged. Table 1 shows that the per cent reduction of population of melon aphids increased with the amount of emulsifier in the spray but not uniformly. It was noted

Table 1.—Effect of the amount of emulsifier on the toxicity of chlordan emulsions.

Emulsifier in Diluted Sprays (1:1000), Per Cent	Number of Tests	Total Aphids Before Spraying	Average Corrected Per Cent Reduction of Population, 1 Day
0.01	6	528	13.1
0.05	6	477	26.0
0.1	6	506	80.3
0.5	6	577	84.4
1.0	6	504	91.6
Check, untreated	6	562	−31.8[1]

[1] Research project supported by the Velsicol Corporation, Chicago, Illinois.

[2] Technical *Velsicol-1068;* Velsicol Corporation.

[1] In this and the following tables the increase in population in the untreated check is indicated by a negative sign.

Table 2.—Effect of the amount of wetter or spreader, sodium lauryl sulfate, on the toxicity of chlordan emulsion.

Sodium Lauryl Sulfate in Diluted Emulsion[1] (1:800), Per Cent	Number of Tests	Total Aphids Before Spraying	Average Corrected Per Cent Reduction of Population, 1 Day
0	5	415	54.4
0.02	5	442	75.9
0.05	5	457	81.7
0.1	5	616	81.1
Check, untreated	5	449	−22.9

[1] The emulsion concentrate contained 20 g. chlordan, 77 ml. kerosene, and 10 ml. *Atlox 1045A*. The total volume was 100 ml.

that the wetting ability of the spray was comparatively poor when the concentration of emulsifier was 0.01 to 0.05 per cent and the change in the reduction of population with increase in emulsifier concentration was relatively slight. At a concentration of 0.1 per cent the spray gave a uniform coverage on the squash leaf and greatly reduced the population as compared to the lower concentrations, i.e., 80.3 per cent reduction of population for 0.1 per cent emulsifier instead of 26.0 per cent for 0.05 per cent emulsifier. When the concentration of the emulsifier was progressively increased from 0.1 to 1.0 per cent there was a small but consistent increase in effectiveness.

It appears from the results that an increase in emulsifier concentration beyond that necessary for the formation of a satisfactory emulsion is needed for maximum effectiveness. The additional emulsifier appears to act chiefly to promote wetting and spreading, since further additions of emulsifier after good wetting has been achieved produced relatively small increases in effectiveness.

Effect of the Amount of Wetter or Spreader.—In the preceding experiment, there was no direct proof that the excess emulsifier did not increase the per cent reduction of population by a change in the nature of the emulsion itself rather than by its wetting and spreading action. For further evidence on this point, sodium lauryl sulfate was added to the diluted standard emulsion just before spraying. This material, being water-soluble but not oil-soluble and being added after the original formation of the emulsion, would be expected to add wetting and spreading properties to the mixture without as radically changing the nature of the emulsion itself as might the additional oil-soluble emulsifier used in the preceding experiment.

As shown in table 2, the addition of 0.02 per cent of the spreader to the diluted emulsion (1:800) increased the per cent reduction of population of melon aphids from 54.5 to 75.9 per cent. Further additions of the spreader up to 0.1 per cent did not appreciably increase the effectiveness of the emulsion.

The effects of adding sodium lauryl sulfate were very similar to the results of increasing the concentration of emulsifier (table 1), and the increase in toxicity in both cases became progressively less after reaching 75 to 80 per cent. However, in order to reach that range, less sodium lauryl sulfate (0.02 per cent) in the diluted emulsion was needed than in emulsifier A (0.09 per cent). This result adds confirmation to the previous conclusion that improved wetting and spreading action is chiefly responsible for the increased effectiveness of emulsions containing more emulsifier than necessary for good emulsification.

Effect of the Nature of Emulsifiers.—The emulsion concentrate contained 20 g. chlordan, 77 ml. kerosene, and 10 ml. emulsifier. All the tested emulsifiers, A, B, C, D, and E (see footnotes under table 3) mixed well with chlordan and kerosene. The diluted emulsions (1:500) varied from poor to good in emulsification. However, after stirring for about 10 minutes the emulsification appeared to be greatly improved, especially in the diluted emulsion containing emulsifier D. The degree of wetting was about the same for all emulsions at a dilution of 1:500. As to the toxicity to melon aphids, no great differences were observed when different emulsifiers was used (table 3).

Effect of the Amount of Chlordan.—For testing the effect of various amounts of chlordan in the diluted emulsion on melon aphids, additional quantities of chlordan were added to the standard emulsion concentrate so that after dilution the concentrations of both kerosene and emulsifier A were kept the same, while the percentage of chlordan was 0.04, 0.1, 0.2, and 0.3 weight per cent. It was found that the reduction of population of

melon aphids in 24 hours increased from 45.1 to 70.4 per cent when the amount of chlordan was increased from 0 to 0.04 per cent. Further increases of the toxicant caused a gradual decrease. When chlordan was increased to 0.3 per cent the reduction of population of aphids was only 49.4 per cent (table 4). The same result was obtained when the experiment was repeated, data of which are not listed. It was observed that as the percentage of chlordan in the diluted emulsion increased, more

Table 3.—Effect of the nature of emulsifiers on the toxicity of chlordan emulsions.

Emulsifier Used in Diluted Sprays (1:500)	Emulsion After Stirring	Number of Tests	Total Aphids Before Spraying	Average Corrected Per Cent Reduction of Population, 1 Day
Emulsifier B[1]	Good	8	725	54.2
Emulsifier A[2]	Very good	8	802	55.5
Emulsifier C[3]	Good	8	793	55.5
Emulsifier D[4]	Fair	8	668	59.8
Emulsifier E[5]	Good	8	889	61.0
Check, untreated		8	775	16.7

[1] Emulsifier B—*Triton B1956;* a modified phthalic glycerol alkyd resin; Rohm & Haas Company, Philadelphia, Pennsylvania.
[2] Emulsifier A—*Atlox 1045A;* a polyoxyethylene sorbitol mixed fatty acid ester; Atlas Powder Company, Wilmington, Delaware.
[3] Emulsifier C—*Duponol OS;* long-chain alcohol sulfate (Cupples 1943); E. I. du Pont de Nemours and Co., Inc., Wilmington, Delaware.
[4] Emulsifier D—*Span 85;* sorbitan trioleate, technical (Cupples 1943); Atlas Powder Company.
[5] Emulsifier E—*Tween 81;* polyoxyalkylene ether of sorbitan mono-oleate; Atlas Powder Company.

and more oily material settled down to the bottom of the container. The drop in toxicity was probably due to a lowering of the concentration of chlordan in the spray caused by a breaking of the emulsion.

To test this assumption, increased amounts of emulsifier A were added to improve the emulsification of the additional amount of chlordan. It was found that when the emulsifier was increased from 0.02 volume per cent in the diluted emulsion to 0.04 and 0.1 volume per cent, the reduction of population of melon aphids increased from 80.2 per cent to 91.4 and 97.4 per cent respectively (Table 5). It appears that in the original formulation the amount of emulsifier was not able to emulsify additional chlordan. With the addition of more emulsifier, more toxicant could be emulsified and therefore, the toxicity was increased instead of decreased. The increased toxicity may be partly due to increases in the amount of

Table 4.—Effect of the amount of chlordan on the toxicity of chlordan emulsions.

Chlordan in Diluted Sprays (1:500) Per Cent	Number of Tests	Total Aphids Before Spraying	Average Corrected Per Cent Reduction of Population, 1 Day
0[1]	6	579	45.1
0.04	6	558	70.4
0.1	6	585	64.3
0.2	6	554	54.3
0.3	6	585	49.4
Check, untreated	6	513	−48.9

[1] Containing 77 ml. kerosene and 10 ml. emulsifier used at a ratio of 0.87:500 instead of 1:500, so that both kerosene and emulsifier were kept constant in all diluted sprays.

emulsifier which would lead to better wetting.

EFFECT OF THE NATURE OF SOLVENTS.—Although chlordan is the only toxicant of chief concern, the solvent used in the dilution of the toxicant may change the properties and eventually affect the final result. In this study the emulsion concentrate contained 20 g. chlordan, 10 ml. emulsifier A and 77 ml. solvent. The solvents used were solvent A, solvent B (see footnote under table 6) kerosene, pine oil, and raw linseed oil. They are quite different in composition and origin, and linseed oil is a drying oil and is non-volatile. At a dilution of 1:500 emulsions containing solvent A, solvent B, kerosene, pine oil, and raw linseed oil gave 49.4, 55.9, 65.7, 61.0 and 79.9 per cent reduction of population of melon aphids respectively (table 6). This variation indicates solvents may differ significantly as diluents for chlordan.

Table 5.—Effect of the amount of emulsifier "A" on the toxicity of chlordan emulsions with an increase in toxicant.

Emulsifier in Diluted Sprays (1:500) with 0.1 Per Cent of Chlordan, Per Cent	Number of Tests	Total Aphids Before Spraying	Average Corrected Per Cent Reduction of Population, 1 Day
0.02[1]	6	518	80.2
0.04[2]	6	604	91.4
0.1[3]	6	660	97.4
Check, untreated	6	508	−21.3

[1] Add 3 g. chlordan to 10 ml. emulsion concentrate containing 2 g. chlordan, 7.7 ml. kerosene and 1 ml. emulsifier.
[2] Add 3 g. chlordan and 1 ml. emulsifier to 10 ml. of the above emulsion concentrate.
[3] Add 3 g. chlordan and 4 ml. emulsifier to 10 ml. of the above emulsion concentrate.

STABILITY OF EMULSION CONCENTRATES.—The emulsifiers tested are of the oil-soluble type, and they formed homogeneous mixtures with kerosene within a short period of time. All the concentrates were kept at room temperature in closed bottles. About 8 months after their mixing when the concentrates were examined again, deterioration was noticed in some of the mixtures. The emulsion concentrates made with emulsifiers A and E were separated into two layers and a large amount of crystals was formed in the concentrate made with emulsifier C. The same separation was also observed when emulsifier A was mixed with kerosene only. Another concentrate containing a heavier grade of petroleum oil,[3] gave a similar separation when emulsifier A was used as an emulsifier. In the formulation with kerosene as a solvent of the toxicant, only emulsifiers B and D remained homogeneously in the concentrates. When solvent A, solvent B, pine oil or raw linseed oil was used instead of kerosene no separation of emulsifier A was observed. In another concentrate containing 30 ml. solvent A and 47 ml. kerosene instead of 77 ml. kerosene only a small amount of material was separated after 8 months of storage.

The separated layers did not go back into solution when shaken. The nature of the change is not known. However, such a deterioration did not seem to have occurred in those concentrates made with solvent A, solvent B, pine oil or raw linseed oil. Solvent A appears to have an action to prevent the separation of emulsifier A in kerosene.

Table 6.—Effect of the nature of solvents on the toxicity of chlordan emulsions.

Solvents Used in Diluted Sprays (1:500)	Number of Tests	Total Aphids Before Spraying	Average Corrected Per Cent Reduction of Population, 1 Day
Solvent A[1]	3	268	49.4
Solvent B[2]	4	407	55.9
Kerosene[3]	4	353	65.7
Pine oil[4]	4	311	61.0
Raw linseed oil[5]	4	349	79.9
Check, untreated	4	303	−24.6

[1] Solvent A—*Velsicol AR-50;* mainly methylnaphthalenes with a distillation range from 440° to 525° F.; Velsicol Corporation, Chicago, Ill.
[2] Solvent B—*Velsicol AR-60;* mainly methylnaphthalenes with a distillation range from 460° to 565° F.; Velsicol Corporation.
[3] No. 9 refined oil; Standard Oil Company, Whiting, Ind.
[4] *Yarmor 302;* Hercules Powder Company, Wilmington, Delaware.
[5] Scientific Oil Compounding Co., Chicago, Ill.

SUMMARY.—In the study of liquid formulations of chlordan in the laboratory, the following conclusions have been reached by using a basic formulation consisting of 20 g. chlordan, 77 ml. kerosene (or other solvents), and 10 ml. emulsifier A (or other emulsifiers).

The wetting ability on squash leaves was comparatively poor when the concentration of emulsifier A in the diluted emulsion (1:1000) was 0.01 or 0.05 volume per cent. At a concentration of 0.1 per cent the spray gave a uniform coverage, and the reduction of population of melon aphids increased to 80.3 per cent instead of 26.0 per cent for 0.05 per cent emulsifier.

The addition of 0.02 per cent of a spreader, sodium lauryl sulfate, to a diluted emulsion (1:800) increased the reduction of population of aphids from 54.4 to 75.9 per cent. Further additions of the spreader up to 0.1 per cent did not increase the effectiveness of the emulsion as much as expected. To compare the effect of spreader with that of emulsifier on the basis of their amount in diluted emulsions and the corresponding toxicity to aphids, it appears that after reaching a complete emulsification spreading action is more important.

On the basis of effectiveness on melon aphids in laboratory tests no significant differences were found when five commercial brands of emulsifiers were used in the emulsion concentrate.

Contrary to the results expected, the effectiveness of the diluted emulsion decreased as the amount of chlordan increased in the standard formulation. When chlordan was increased from 0.04 (original formulation) to 0.3 weight per cent in the diluted emulsion, the reduction of population of aphids decreased from 70.4 to 49.4 per cent. However, when the emulsifier was increased from 0.02 volume per cent (original formulation) to 0.04 and 0.1 volume per cent in the diluted emulsion containing 0.1 per cent chlordan the reduction of population of aphids in-

[3] *Prorez "D"* 100 seconds viscosity, Standard Oil Company.

creased from 80.2 per cent to 91.4 and 97.4 per cent respectively. It appears that in the original formulation the amount of emulsifier is not able to emulsify additional chlordan. With the addition of more emulsifier, more toxicant can be emulsified and therefore, the toxicity is increased instead of decreased.

There was not much difference in the effectiveness of emulsions when solvents of quite different nature were used, except raw linseed oil which gave a better result.

In emulsion concentrates made with kerosene, emulsifiers A, C, and E did not form mixtures as stable as emulsifiers B and D. However, such slow deteriorations did not seem to be found in those concentrates made with solvent A, solvent B, pine oil, or raw linseed oil. Solvent A appears to have an action to prevent the slow separation of emulsifier A in kerosene.

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DDT Residues on Alfalfa Hay and Seed Chaff

RAY F. SMITH, O. H. FULLMER, and P. S. MESSENGER,[1,2] *University of California, Berkeley*

In view of the importance of DDT residues on alfalfa and other forage crops in relation to the secretion of DDT in milk, the residues found in samples of alfalfa hay and alfalfa seed chaff are summarized in this article. Very little information has been published concerning the residues of DDT on forage crops. Hoskins (1945) reported 29 ppm DDT (fresh weight basis) on alfalfa which had been treated twice with 28 pounds of 3 per cent DDT dust 44 and 27 days prior to sampling. Lieberman (1946) found 17 ppm before threshing in alfalfa seed plots 95 to 96 days after treatment, and less than 10 ppm in the chaff after threshing. Wilson, *et al.* (1946) and Lardy (1948) found that one ground application of 35 pounds 5 per cent DDT dust put 9 to 13 ppm on pea vines, whereas airplane application resulted in 2 to 3 ppm. Carter (1948) stated that 1 to 2 pounds of actual DDT per acre on alfalfa gave 2 to 48 ppm DDT at harvest. Arant (1948) found that DDT persisted on peanut hay several weeks after treatment, the amount varying from 2 to 31 ppm.

In connection with studies in the control of the alfalfa butterfly, *Colias philodice eurytheme* Bdv. on alfalfa grown for hay, and Lygus bugs, *Lygus* spp. on alfalfa grown for seed, numerous samples of hay and straw were taken from experimental plots and commercially applied treatments. The samples from individual alfalfa seed fields were taken immediately before and after harvest following weathering periods which ranged 29 to 69 days. These samples were composite samples taken at several stations in the field. The samples from any given alfalfa hay field were taken after cutting and had comparatively short weathering periods. These samples were composite samples taken from the inside of several scattered windrows. All samples were allowed to reach air dryness before analysis. The importance of moisture content is shown by two sets of samples which analyzed 7.4 and 5.2 on the basis of their green weight but which analyzed 18.2 and 17.1 on the basis of air-dry weight. It is estimated that the moisture content of the majority of samples was slightly below ten per cent at the time of analysis.

ANALYTICAL METHOD.—Samples of 250 to 300 grams of alfalfa were weighed out in one gallon wide-mouthed glass jars fitted with tight lids. The samples were shaken with 400 cc. of benzene for 3 to 4 minutes, and the benzene drained off through a cotton plug. This extract was then analyzed for DDT content using a

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[2] O. H. Fullmer and P. S. Messenger are chemists on the staff of the University of California.

Table 1.—Residue of DDT on samples of alfalfa seed straw taken before and after harvest. July-September, 1946.

Source of Sample	Pounds per Acre of Application	Per Cent DDT	Pre-Threshing Samples		Post-Threshing Samples	
			Days of weathering	DDT, ppm	Days of weathering	DDT, ppm
Blythe	39	10	67	3.9, 0.9	—	—
Blythe	26	10	—	—	51	5.6, 5.8
Blythe	42	5	66	20.0	69	4.5, 6.0
Blythe	41	5	41	6.5	46	6.7
Blythe	41	5	—	—	65	4.3
Blythe	41	5	42	14.5	53	3.7
Blythe	38	5	67	1.6, 0.4	—	—
Hemet	38	5	62	5.1, 8.0	62	5.6
Blythe	36	5	55	3.7	59	4.5
Blythe	36	5	31	6.8	36	5.0, 1.9
Patterson	35	5	—	—	60	4.5
Hemet	34	5	60	1.6	63	0.6, 0.0
Hemet	34	5	63	14.1	—	—
Hemet	33	5	68	0.7	—	—
Blythe	33	5	67	2.9, 0.0	—	—
Blythe	33	5	54	2.3, 3.7	—	—
Blythe	33	5	29	4.5	33	0.0, 1.5
Blythe	33	5	40	2.7	43	0.0, 0.0
Blythe	33	5	45	6.2	47	4.2, 4.7
Blythe	32	5	40	2.9	47	0.2, 0.3
Hemet	31	5	53	6.9	—	—
Hemet	31	5	53	7.7	—	—
Blythe	30	5	70	4.2	84	16.0
Blythe	30	5	38	0.0	52	2.3
Hemet	29	5	58	6.6, 6.4	68	0.0, 0.0
Blythe	29	5	44	7.9	54	12.9
Blythe	29	5	—	—	50	2.8, 8.9
Blythe	28	5	41	13.6	48	4.0
Patterson	28	5	—	—	—	0.5
Hemet	27	5	62	5.1, 8.0	62	5.6
Patterson	26	5	—	—	61	5.5, 12.4
Blythe	15	5	—	—	24	0.0, 2.6
Blythe	Heavy Drift	5	41	4.3	46	3.7
Patterson	39	4	—	—	67	9.0, 9.7
Patterson	31	4	—	—	63	8.5, 7.6

total chloride method similar to the one described by Wichmann, *et al.* Some samples were also run following the colorimetric method described by Wichmann as a check on the total chloride method.

All results are in ppm DDT as determined by the total chloride method. To convert to p, p' isomer 70 per cent of the reported values may be used, since that is approximately the percentage of p, p' isomer in technical DDT (Haller *et al.*, 1945).

Alfalfa and similar forage crops characteristically give very uneven and variable residues. This is due to a series of interrelated factors. The amount of hay per acre is exceedingly variable and commonly ranges from three-fourths of a ton to over two tons. This variation occurs not only from field to field but from point to point within a field. Such factors as soil moisture, hardpan, alkali, gravel, disease, and insect infestation are reflected in the growth and stand of the alfalfa. The method and rate of curing would appear to be important as they affect the moisture content of the hay. In addition, the evenness of the insecticide application, type of insecticide application, weathering conditions, days of weathering, and others affect the residue. It is impractical if not impossible to allow for all of these conditions in sampling.

Residues on Straw from Alfalfa-Seed Fields.—Residue determinations were made in 1946 from three widely separated localities in California—Blythe in eastern Riverside County, Hemet in western Riverside County, and Patterson in western Stanislaus County. The sources of these samples, rate of DDT application, type of sample, weathering period,

Table 2.—Samples of alfalfa hay taken from treated fields. 1946.

SOURCE OF SAMPLE	POUNDS PER ACRE OF APPLICATION	PER CENT DDT	DATE TREATED	DAYS OF WEATHERING	DDT PPM
Dos Palos	42	0.5	Aug. 8	16	1.0, 1.8, 1.7
Dos Palos	—	4.0	—	—	25.4, 38.7, 60.3
Dos Palos	—	4.0	—	—	40.9, 12.4, 20.6
Imperial	15	5.0	Aug. 4	35	0.0
Imperial	25	5.0	July 12	21	74.0[1]
Imperial	25	5.0	July 12	25	6.2, 6.1
Imperial	16	5.0	July 9	24	4.7
Imperial	16	5.0	July 10	23	6.9

[1] Poor application.

and amount of DDT recovered are shown in table 1. Although there is a great deal of variation in these data, appreciable DDT remained on the alfalfa straw after long weathering periods and threshing. The 74 samples ranged from 0.0 to 20.0 ppm and averaged 4.9 ppm. In general, there was some reduction in the DDT following threshing.

ALFALFA HAY SAMPLES.—Fifteen samples of alfalfa hay which had been dusted previously with DDT were analyzed in 1946 and the data obtained are summarized in table 2. In 1947, the work was continued and considerably expanded. The data from fields which were sprayed by airplane with a DDT-water emulsion at the rate of 5 gallons per acre are given in table 3. The results of analyses of samples taken from fields which were dusted by airplane are given in table 4. On the basis of these data it can be concluded that this type of spraying gives markedly higher residues than when equal amounts of DDT are applied as dusts. As with the alfalfa seed chaff, the residues are exceedingly variable, ranging from 0.0 to 12.1 ppm for 0.25 pound of DDT per acre in a spray, and from 0.0 to 3.1 ppm for a comparable amount of DDT in a dust. The duration of the weathering period does not seem to be a critical factor. For example, in one field the residue was 7.3 ppm one day after cutting and was still 6.2 ppm 20 days after cutting. In another case, samples taken 10, 14, 16 days after treatment had 26.0, 18.2, and 17.1 ppm respectively. It would seem in this latter case that variations in moisture content were more critical.

Additional data have been obtained from fields where DDT was applied by ground machine. The results are very similar to the applications by airplane. One-quarter pound of actual DDT per acre in a spray applied by a ground machine gave 5.4 and 5.3 ppm after 15 days of weathering in one case, and 6.2 ppm after 20 days of weathering in another case. Approximately 0.5 pound of actual DDT per acre applied as 5 per cent DDT dust by a rather inefficient ground duster gave exceedingly variable results which ranged from 0.9 to 18.6 and averaged 5.8 ppm.

Table 3.—Residues of DDT on alfalfa hay following spraying by airplane. San Joaquin Valley, 1947.

ACTUAL DDT PER ACRE	WEATHERING PERIOD (DAYS)	DDT PPM
1 lb.	18	36.4
	13	47.2
	9	42.7
0.75 lb.	23	11.0, 10.9, 6.8
	20	9.7
0.5 lb.	23	4.7, 4.6, 3.7
	21	4.6
	10	26.0
0.25 lb.	—	24.0
	9	7.1
	9	8.2
	12	2.6, 1.8, 1.0
	12	2.2, 0.0, 0.0
	14	9.8
	14	7.2, 5.1, 8.2, 7.8
	23	7.3
	23	0.0, 0.0, 0.0
	24	6.8
	27	5.8, 12.1

Results from one field which was sprayed by airplane with 0.25 pound of actual DDT per acre indicate that the DDT does not decompose appreciably when the alfalfa is stored in bales. This field was treated on August 12, 1947, and cut on August 22. Samples taken from the inside of dry windrows on August 26 showed 7.2, 5.1, and 8.2 ppm of DDT. Samples taken from bales at various times

Table 4.—Residues of DDT on alfalfa hay following dusting by airplane. San Joaquin Valley, 1947.

Per Cent DDT	Pounds of Dusts per Acre	Actual DDT per Acre (Pounds)	Weathering period (Days)	Residue ppm DDT
Five	35	1.75	12	15.3
	30	1.50	15	8.4
	30	1.50	11	10.3
	30	1.50	10	3.7
	25	1.25	19	3.9
	20	1.00	13	9.7
	20	1.00	13	3.1
	20	1.00	19	8.8
Four	30	1.20	—	2.3
	25	1.00	20	6.2
	20	0.80	11	3.9
	20	0.80	20	9.8
Three	30	0.90	15	8.7
	30	0.90	15	0.0, 0.0, 0.6
	20	0.60	19	4.2
	20	0.60	14	6.9
	20	0.60	10	8.5
Two	30	0.60	14	7.9
	25	0.50	20	5.2
One	30	0.30	15	0.0, 0.0, 0.7
	30	0.30	23	3.1, 2.2, 1.8
	30	0.30	23	3.1, 1.9, 1.3
	25	0.25	14	0.0
One-half	30	0.15	23	1.9, 1.4, 1.4
	30	0.15	23	0.8, 0.5, 0.0

during storage analyzed as follows: September 4, 1947, 10.0 ppm; November 13, 7.0 ppm; November 28, 3.0 and 1.9 ppm; December 9, 13.0 and 13.9 ppm; December 18, 3.3 and 5.7 ppm; January 6, 1948, 8.3 ppm; January 20, 8.3 ppm; and February 2, 1948, 10.2 ppm.

CONCLUSIONS.—DDT is very persistent on alfalfa hay and alfalfa seed chaff, and although the results are extremely variable, appreciable DDT can be expected even when the dosage is as low as a quarter of a pound of actual DDT per acre. None of the residues found approach the acute toxic dosages for mammals and the only hazard which exists is that which arises from the storage of DDT in fat tissue and its secretion in milk. Until this hazard is defined and the Food and Drug Administration sets a tolerance for DDT in meats and milk, DDT cannot be recommended for use on forage crops at the dosages studied in this investigation.

SUMMARY.—Alfalfa hay and alfalfa straw from a wide range of localities in California have been analyzed for DDT following spraying and dusting. Straw from alfalfa seed fields which had been dusted for lygus bugs with five per cent DDT showed from 0.0 to 20.0 ppm even after long weathering periods. Alfalfa hay from fields treated with DDT for the control of the alfalfa butterfly showed a variable amount of DDT due to variations in application, growth of the alfalfa, weathering, and moisture content of the hay. It ranged for dusts from 0.0 to 1.9 ppm at the lower dosage (30 pounds of 0.5 per cent DDT per acre), and from 3.7 to 10.3 ppm at the higher dosages (30 pounds of 5 per cent DDT per acre). For sprays, it ranged from 0.0 to 12.1 ppm for 0.25 pound of actual DDT per acre, and from 36.4 to 47.2 for 1 pound of actual DDT per acre.

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Secretion of DDT in Milk of Dairy Cows Fed Low-Residue Alfalfa Hay

RAY F. SMITH, W. M. HOSKINS, and O. H. FULLMER[1]
University of California, Berkeley

It is now a well established fact that lactating animals on a diet containing DDT may secrete this substance in their milk. The importance of this matter is increasing since DDT is now being used to control insect pests of alfalfa; mosquitoes in permanent pastures, European corn borer on corn, pea weevil and pea aphids on peas, and in numerous other situations where the treated plants are fed to cattle. Up to 36 ppm DDT have been reported in the milk of cows that had grazed on DDT-sprayed pasture or fed on DDT-sprayed hay containing 184 ppm DDT residue (Carter 1947, 1948; Schechter, Pogorelskin, & Haller, 1947; Arant 1948). A Jersey cow fed 24 grams DDT per day for 5 months had 44 ppm DDT in her milk at the end of the feeding period, 15 ppm 1 week after feeding of DDT was discontinued and 7 ppm 3 weeks later (Wilson *et al.* 1946; Allen *et al.* 1946). Five cows receiving pea silage containing about 100 ppm DDT for approximately four months had 15.6 ppm DDT in their milk (Wilson *et al.*, 1946; Allen *et al*, 1946; Lardy 1948). Two large Holstein cows which received 40 to 80 pounds of pea silage per day, containing less than 1 ppm DDT, had no detectable DDT in their milk after over 4 months of feeding (Wilson *et al.* 1946; Allen *et al.* 1946). Three cows fed corn silage which contained from 3.2 to 19.2 ppm DDT had 0.3 ppm DDT in the milk on the thirty-first day, 0.2 ppm on the forty-second day, 0.3 ppm on the sixty-fifth day, 0.1 ppm on the eighty-fifth day, and 0.5 ppm on the hundredth day of feeding. Five cows which received pea silage containing from a trace to 1 ppm DDT never had over 0.5 ppm in their milk (Wisconsin Agr. Expt. Sta. 1947; Lardy 1948). Where no provision was made to prevent licking, cows sprayed with DDT secreted it in the milk (Anon. 1948; Howell *et al.* 1947). Milk from cows receiving 43 to 97 mg. DDT/kg./day was toxic to houseflies, but was not toxic when the cows received 12 mg./kg./day (Wing & Crisler 1948).

It is clear that even at very low dosages appreciable DDT will appear in the milk. There is some indication from the results cited that the type of diet affects the amount of DDT secreted in the milk on a given dosage of DDT. At the present time, no published information is available on the secretion of DDT in milk of dairy cows fed alfalfa hay contaminated with a small residue of DDT.

EXPERIMENTAL PROCEDURE.—Alfalfa hay from a large field which was sprayed with 0.25 pounds of actual DDT in 5 gallons of water per acre was fed to a grade dairy herd for a period of over 3 months. The field was treated on August 12, 1947, and cut 10 days later. The hay was stored in bales in the stack until the time of feeding. Analyses of hay taken in the field from green windrows 14 days after treatment showed 7.2, 5.1, 8.2, and 7.8 ppm. Later samples taken from the bales showed 10.0 ppm on September 4, 5.6 ppm on November 13, 1.9 and 3.0 ppm on November 28, 13.0 and 13.9 on December 9, 3.3 and 5.7 on December 18, 8.3 on January 6, 8.3 on January 20, and 10.2 on February 2. Variation of this magnitude appears to be normal with alfalfa (Smith *et al.*, 1948). The herd was removed from pasture on November 21, 1947, and placed in a feed lot where it received this DDT-treated hay as the whole ration until February 8, 1948. From February 8 to March 2, approximately 50 per cent of the ration was replaced with untreated alfalfa hay and thereafter only untreated hay was fed. These cows were not sprayed with DDT at any time during the course of the experiment. It is estimated that the cows ate an average of 36 pounds of alfalfa hay each per day. Milk samples were taken at the evening milking from each cow every other day for the first month of feeding and then approximately once a week for the remainder of the experiment. Selected samples were analyzed for DDT. Milk yields for each of these six cows were taken every day for one week, then every

[1] The authors wish to acknowledge the aid of various entomologists and farmers who have assisted in this problem. We especially are indebted to Floyd E. Redfern, Glenn Clothier, W. W. Allen, P. S. Messenger, and Arthur Walz.

week for 2 months and then every 2 weeks for the remainder of the experiment.

ANALYSIS OF MILK AND CREAM SAMPLES —The whole milking was mixed thoroughly and a 200 cc. portion poured into a glass bottle fitted with a cork stopper. The samples were immediately put under refrigeration and kept cold until analyzed.

At the time of analysis the samples were warmed to room temperature in a water bath and then mixed thoroughly by shaking for 2–3 minutes or until the cream appeared to be completely mixed into the sample. A 50 gram sample was then weighed immediately into a Waring blender cup. 50 cc. of 95 per cent ethyl alcohol and 75 cc. of petroleum ether[1] were then added and the mixture blended for 5 minutes. Fifty grams of anhydrous sodium sulphate was then added and the sample blended for an additional 2 minutes. The mixture was then transferred into centrifuge tubes and centrifuged until a clean separation was obtained (approximately 5 minutes at 800 rpm). The ether layer was recovered for the subsequent DDT analysis.

The amount of ether recovered by the above method was always between 65 and 68 cc. To check the completeness of the extraction procedure, the residue remaining in the centrifuge tubes after the first extraction was re-extracted numerous instances by the same method as the above. In each case the amount of DDT recovered in the second extraction was just slightly less than the theoretical amount left in the 7–10 cc. of ether that was not recovered from the first extraction, assuming that in the blending all the DDT present in the milk was distributed evenly in the ether. Accordingly the final results were calculated on the basis of the volume of ether recovered.

The analysis for DDT was made as follows. The ether was evaporated on a water bath and the residue taken up in 50 cc. of chloroform. The fat was removed from the chloroform solution by a method recommended by Schechter, *et al.*, (1947) which consisted of extraction with two 20 cc. portions of a 5 per cent solution of anhydrous sodium sulphate in concentrated sulfuric acid, one 20 cc. portion of a 1:1 mixture of concentrated sulfuric acid and fuming sulfuric acid, and a final 20 cc. portion of the sulfuric acid-sodium sulphate mix. The chloroform layer was freed of acid with a 5 per cent sodium bicarbonate solution, drained into a small flask, and taken just to dryness at 100° C. The residue was then analyzed by the nitration procedure outlined by Schechter *et al.* (1947).

The analysis of butter was carried out by putting the weighed samples directly into chloroform. They were then treated in the same manner as described above.

The standard curve necessary for the calculation of the DDT content was determined using a sample of commercial technical DDT similar to the one used in the spraying experiments. Known amounts of the DDT were added to ether extracts of 50 gram milk samples from control cows, following the same procedure as outlined above. The density measurements were made at 600 millimicrons using a model DU Beckman spectrophotometer.

RESULTS.—The results of this experiment are summarized in figures 1 and 2. Figure 1 shows the daily milk yield, DDT content of the milk and total DDT secreted for each of the cows. Figure 2 gives the average of the above for the herd. There were no detectable external effects on any of the animals attributable to this rate of feeding DDT. During the experimental period the butterfat content of the milk ranged from 3.5 to 5.3 per cent and averaged 4.5 per cent. A sample of butter made from milk taken on January 20 analyzed 65 ppm DDT, which is in close agreement with the figure calculated from the DDT content of the whole milk and the percentage of butterfat, assuming all DDT in the latter. A sample of butter made from milk taken from cow No. 2 analyzed 12 ppm DDT on April 22, *i.e.*, 7 weeks after the change to untreated hay. A seventh cow which, while dry, had been receiving the same DDT-treated hay since November 21, dropped a normal heifer calf on February 16. This cow's colostrum milk contained 1.3 ppm DDT, while samples of milk taken at this time from other cows which had been fresh for several months averaged 1.35 ppm DDT. On February 27 this cow again had 1.3 ppm DDT in her milk, while others long fresh had 1.25 ppm. On March 26, 24 days after DDT feeding was discontinued completely,

[1] *Skellysolve B* was found to be very satisfactory.

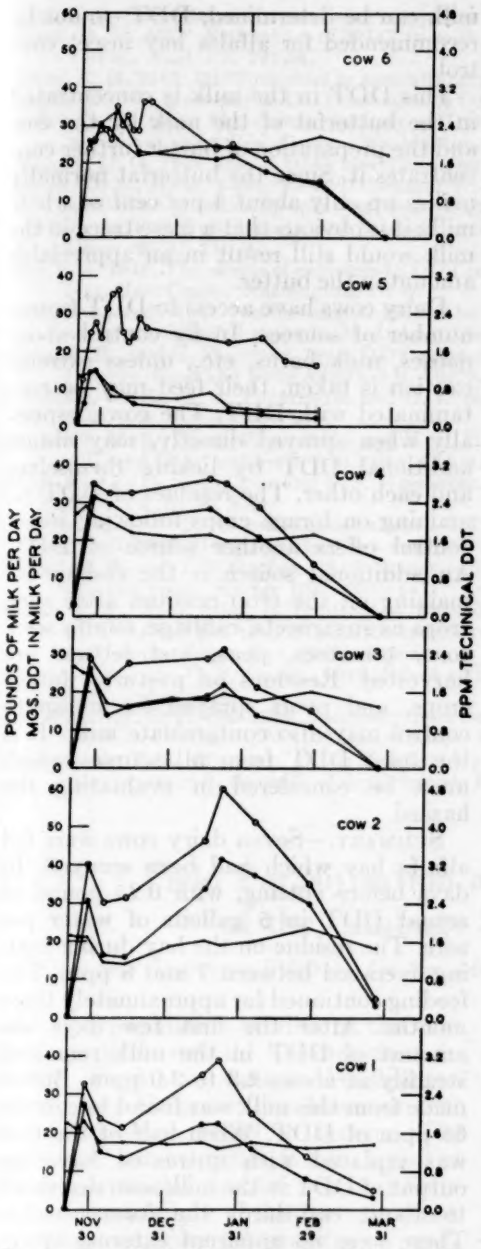

FIG. 1.—Pounds of milk per day (small dots), milligrams of DDT in total milk per day (solid circles), and ppm of DDT (open circles) in the milk of six cows receiving DDT-treated alfalfa hay.

cow No. 7 had no detectable DDT in her milk.

DISCUSSION.—Within 3 days after starting on the DDT-treated hay, the content of DDT in the whole milk rose quickly to a level (2.3 to 3.0 ppm) which was maintained more or less throughout the whole period the cows received only treated hay. The milk production dropped slightly at first, as would be expected upon removal from pasture, and then remained rather constant. Since the milk production was rather constant, the total amount of DDT secreted daily closely followed the ppm DDT curve. It is of interest that on a diet that furnished approximately 126 mg. DDT per cow per day from 18.9 to 29.0 mgms. DDT per day were secreted in the milk on the average and certain cows on some days secreted as high as 41 mgms. of DDT. When half of the feed was replaced on February 8 with untreated hay, the output of DDT in the milk soon decreased to about two-thirds or less of the former value.

The last analyses on whole milk, made 24 days after the cows were put on uncontaminated feed, showed at least a trace of DDT in all samples but not over 0.5 ppm

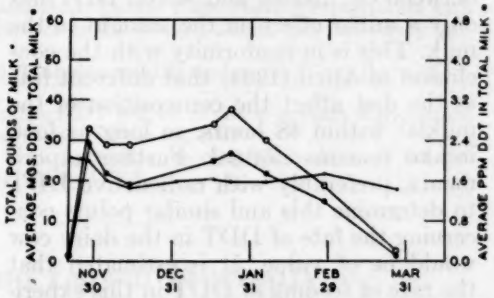

FIG. 2.—Average pounds of milk per day (small dots), average milligrams of DDT in total milk per day (solid circles), and average ppm of DDT (open circles) in the milk of cows receiving DDT-treated alfalfa hay.

in any one. The 12 ppm DDT found in butter from cow No. 2 on April 22, *i.e.* after 51 days on uncontaminated feed, corresponds to about half a ppm in the whole milk. The secretion of DDT so long after intake ceased probably was due to slow loss from that stored in the body fat (*cf.* Carter 1948). The amount was very small in comparison with the 7 ppm in the milk a month after a daily intake of 24 grams was stopped (Wilson *et al.* 1946). Evidently the level to which stored DDT reaches is a function of the intake.

There was considerable variation from cow to cow in the total amount of DDT secreted (3.5 to 41.4 mg. per day), and in the concentration of DDT (1.7 to 4.8 ppm) in the milk. It is of interest to note that cow No. 2, which had the most DDT

in her milk, was the most aggressive at the manger and had the highest butterfat content. Little can be offered to explain the fluctuations in the secretion of DDT other than the normal variation of the cows and the uneveness of the residue on the hay. Cow No. 5 was dehorned in early December and this undoubtedly accounts for her low milk production.

Cow No. 7, which came fresh on February 16, had no more DDT in her colostrum milk and subsequent milk than other cows in the herd. Similar information was obtained by Wilson and his coworkers (Wisconsin 1947; Lardy, 1948). At this level of feeding it would seem that the daily intake is more critical than the total intake or the amount stored in the fat. In other words, absorbed DDT circulates in the blood long enough for a considerable fraction to be removed during the secretion of milkfat and any exchange between circulating and stored DDT has only a minor effect on the amount in the milk. This is in conformity with the conclusion of Allen (1934) that different fats in the diet affect the composition of the milkfat within 48 hours, so long as food intake remains normal. Further experiments, preferably with radioactive DDT to determine this and similar points concerning the fate of DDT in the dairy cow would be of value. It is estimated that the rate of feeding of DDT in this experiment was approximately 0.25 mg. per kg. At a more or less comparable feeding of DDT in corn silage, the Wisconsin workers (Wisconsin 1947; Lardy 1948) found only about 0.10 as much DDT in the milk. It is possible that in the feeding of laxative silage less DDT is absorbed than from the dry alfalfa hay. The amount absorbed by the cow from various types of diets would seem to be an important factor in evaluating the hazard of DDT residues. For the present, it can be stated that with the dosages of DDT normally used for the control of alfalfa insects (0.25 pounds of actual DDT per acre and higher) appreciable amounts of DDT can be expected in the milk. Until such time as the hazard of these low amounts in the milk can be determined, DDT cannot be recommended for alfalfa hay insect control.

This DDT in the milk is concentrated in the butterfat of the milk by the cow and the preparation of butter further concentrates it. Since the butterfat normally makes up only about 4 per cent of whole milk, it is obvious that a mere trace in the milk would still result in an appreciable amount in the butter.

Dairy cows have access to DDT from a number of sources. In fly control about dairies, milk barns, etc., unless extreme caution is taken, their feed may be contaminated with DDT. The cows, especially when sprayed directly, may obtain additional DDT by licking themselves and each other. The residues of DDT remaining on forage crops following insect control offers another source of DDT. An additional source is the residue remaining on the crop residues after such crops as sugarbeets, cabbage, alfalfa seed, corn, tomatoes, peas, and lettuce are harvested. Residues on pastures, forage crops, and pools sprayed for mosquito control may also contaminate milk. It is the total DDT from all sources which must be considered in evaluating the hazard.

SUMMARY.—Seven dairy cows were fed alfalfa hay which had been sprayed, 10 days before cutting, with 0.25 pound of actual DDT in 5 gallons of water per acre. The residue on the hay during feeding averaged between 7 and 8 ppm. The feeding continued for approximately three months. After the first few days the amount of DDT in the milk remained steadily at about 2.3 to 3.0 ppm. Butter made from this milk was found to contain 65 ppm of DDT. When half of the feed was replaced with untreated hay, the output of DDT in the milk soon decreased to about two-thirds the former value. There were no apparent external symptoms in the cows nor was the milk production affected. More information is needed on the effect of low rates of feeding, type of ration, butterfat production, type of cow, and the fate of DDT in the cow.

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Field Parasitization and Larval Mortality of the Cabbage Seedpod Weevil

CHARLES F. DOUCETTE, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

During population studies of the cabbage seedpod weevil, *Ceutorynchus assimilis* (Payk.) in western Washington and western Oregon it was observed that numerous larvae failed to mature. The absence of an emergence hole in a pod in the area of larval damage was a definite indication of failure of the larva to reach maturity. Samples of cruciferous pods were therefore examined to determine the extent of such larval mortality. The data are summarized in table 1.

Parasites that complete their development on weevil larvae also escape from the pods through emergence holes, and it is not possible to determine whether a hole in a dry pod was made by a weevil larva or a parasite adult. Hence, the data in table 1 do not include the mortality of larvae killed by parasites that emerged.

It is evident from these studies that larval mortality is relatively high in plants of the genus *Brassica* (cole crops), but very low in those of the genus *raphanus* (radish). There are two principal reasons for the low mortality in the latter. Radish seeds are fairly large and many larvae are able to complete their development on single seeds. There is much less movement from seed to seed within the pods. Furthermore, parasites rarely attack larvae in radish pods. The larvae in the seeds appear to be beyond the reach of the ovipositors of the parasites.

All the causes of mortality have not been determined. Parasitization is a very important factor. But in green pod examinations numerous dead larvae have been

[1] In cooperation with the Northwestern Washington Experiment Station, Mt. Vernon, Wash.; the Washington State Department of Agriculture; Skagit County, Wash.; and the Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture.

Table 1.—Mortality of larvae of *Ceutorynchus assimilis* in cruciferous seedpods, as evidenced by lack of emergence holes.

Host	Samples	Larvae	Mortality
	Number	*Number*	*Per Cent*
Examinations in 1943			
Cabbage	4	765	63
Kale	1	105	72
Rutabaga	1	75	25
Radish, cultivated	1	37	5
Radish, common wild	1	80	9
Examinations in 1944			
Cabbage	21	846	45
Turnip, root-type	4	308	37
Turnip, Shogoin	2	101	16
Rutabaga	3	53	34
Kale	3	172	53
Chinese cabbage	4	492	15
Brussels sprouts	1	67	49
Borccoli, green	1	106	70
Kohlrabi	1	92	100
Brassica campestris	4	233	27
Brassica kaber (arvensis)	2	32	47
Radish, cultivated	3	166	7
Radish, common wild	2	24	8
Examinations in 1945			
Cabbage	44	2,852	49
Turnip, root-type	11	666	35
Turnip, Shogoin	2	56	14
Rutabaga	4	269	34
Kale	3	106	42
Brussels sprouts	2	158	70
Rape	2	145	15
Kohlrabi	1	331	94
Broccoli, green	1	71	69
Mustards	3	102	22
Brassica campestris	18	1,290	36
Brassica kaber (arvensis)	8	140	34
Brassica juncea	2	109	54
Radish, cultivated	6	139	3
Radish, common wild	6	205	4
Raphanus raphanistrum	4	95	2
Examinations in 1946			
Cabbage	1	14	64
Turnip, root-type	2	41	42
Rutabaga	2	84	16
Kohlrabi	1	367	99
Kale	1	271	53
Brassica campestris	1	242	30

found with no evidence of parasite attack (eggs or larvae). Some of them may have been paralyzed by parasite females that failed to deposit eggs. Some larvae have been found pinched by proliferating tissue between the seeds in the pods. The nature of the inter-embryonic tissue varies considerably in the different host plants. It is prominent in cabbage, root-type turnip, kale, broccoli, and Brussels sprouts, of moderate density in rutabaga, rape, *Brassica campestris, B. kaber (arvensis), B. juncea,* and mustards, and very sparse in Shogoin turnip and Chinese cabbage. In kohlrabi it is pronounced, and is considered as the primary cause of the almost complete larval mortality that has been observed in this plant. The larvae in kohlrabi pods seldom developed beyond the half-grown stage.

In one measurement of the extent of parasite attack, 500 cabbage pods (variety Resistant Detroit) were placed in closed containers fitted with vial traps. The parasite adults emerging from the pods were caught in the vials and removed. After the emergence period the pods were opened, the total number of larvae that had been present was determined, and emergence holes in the pods were counted. The 500 pods were attacked by 661 larvae, and there were 221 holes in the pods representing emergenees of either nature larvae or adult parasites. Since 161 parasite adults were obtained in the traps, only 60 larvae were able to complete their develop ment. The remaining 440 larvae had died in various stages of development from undeteriminable causes.

Parasite adults have been obtained from various cruciferous pods from several localities in the Pacific Northwest. Usually the pods were placed in closed containers with vial traps, in which the adults were caught. Several adults were collected on cruciferous plants in the laboratory planting at Summer. A very few larvae which were found in dry pods in the fall and winter months were reared to the adult stage. Determinations of these adults have been made by A. B. Gahan.

From pods grown at the indicated localities the following parasites were obtained:

Trichomalus fasciatus Thom.
Skagit County, Wash. (several localities)
San Juan Island, Wash.
Sumner, Wash.
Corvallis, Oreg.
Logsden, Oreg.

Necremnus duplicatus Gahan
Skagit County, Wash. (several localities)
San Juan Island, Wash.
Sumner, Wash.
Logsden, Oreg.
Moscow, Idaho

Disema sp.

Skagit County, Wash. (several localities)
San Juan Island, Wash.
Sumner, Wash.
Corvallis, Oreg.
Logsden, Oreg.
Moscow, Idaho.

Eurytoma sp.

Sumner, Wash.
Corvallis, Oreg.
Logsden, Oreg.
Moscow, Idaho

Trichomalus sp.

Sumner, Wash.
Moscow, Idaho

The adults collected on cruciferous seed plants at Sumner were determined as *Trichomalus fasciatus*, *Eurytoma* sp., and *Disema* sp.

All the adults reared from larvae found in dry pods were found to be *Eurytoma* sp., except from one sample of *Brassica campestris* pods collected on San Juan Island in which there was a single specimen each of *Eupelmella vesicularis* and *Tetrastichus* sp., which Gahan considers as probably secondaries. These *Eurytoma* adults represent the following localities, several of which are not represented in the two series above:

Washington:	Oregon:
Lynden	Corvallis
Mt. Vernon	Logsden
San Juan Island	
Orcas Island	
Sumner	
Alderton	
McMillan	
Montesano	

Four species appear to be generally distributed in the Pacific Northwest. *Trichomalus fasciatus* has been found in both western Washington and western Oregon, but it did not appear in the Moscow, Idaho, samples. This species has been reported as common in Europe. *Necremnus duplicatus* was originally described by Gahan from specimens collected in Skagit County, Wash. It has been reared from pod samples from western Washington, western Oregon, and Moscow, Idaho. Males with pectinate antennae were occasionally encountered. It seems to be moderately abundant in northern Washington, but only a few were obtained in the other localities. *Eurytoma* sp. adults were reared in the summer months from material from Sumner, Wash., as well as from Corvallis, and Logsden, Oreg., and Moscow, Idaho. None were obtained from pods from Skagit County or vicinity. However, from overwintering larvae adults were reared from Whatcom, Skagit, and San Juan Counties as well as from Pierce and Grays Harbor Counties in Washington and Benton and Lincoln Counties in Oregon. It seems to be fairly abundant in Pierce County but scarce in the Skagit area. *Disema* sp. was found in collections from western Washington, western Oregon, and Moscow, Idaho. Little information is available concerning this form. It seems to be abundant in all the localities where it has been found.

A species of *Trichomalus* differing from *T. fasciatus* has been found at Sumner, Wash., and Moscow, Idaho. The collections indicate a light to moderate abundance at both localities. A single specimen of *Amblymerus* sp. was obtained from pods gathered at La Conner, Wash., and a single specimen of *Zatropis* sp. was taken on a plant at Sumner, Wash.

SUMMARY.—Observations of cruciferous seed pods in western Washington and western Oregon indicate that numerous larvae of the cabbage seedpod weevil, *Ceutorhynchus assimilis* (Payk.), fail to mature. The mortality was found to be high in many of the important host plants in the genus *Brassica*, but comparatively low in the genus *Raphanus*. Many larvae die in the spongelike tissue between the seeds in the pods. In kohlrabi particularly the nature of this tissue is considered responsible for the almost complete larval mortality. In radish pods there is much less larval movement from seed to seed, as many of the larvae complete their development on single seeds.

Several parasites that attack the larvae cause considerable larval mortality. Four parasitic forms are common in the Pacific Northwest: *Trichomalus fasciatus* Thom., *Necremnus duplicatus* Gahan, *Eurytoma* sp., and *Disema* sp. A species of *Trichomalus* differing from *I. fasciatus* has been found in moderate abundance at Sumner, Wash., and Moscow, Idaho.

Effect of Plant Development on Resistance of Corn Hybrids to European Corn Borer[1]

L. H. Patch, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*, and H. O. Deay, *Purdue Agricultural Experiment Station*

Some inbred lines of dent corn and their hybrids have shown consistent inherent resistance to the survival of larvae of the European corn borer, *Pyrausta nubilalis* (Hbn.). The work on differential resistance with these lines was done when leaves of the plants were in the whorl during the hatching period, the usual condition in dent corn during egg laying of the June generation of moths, and has been reported (Patch *et al.* 1942, Patch & Everly 1945). Patch & Everly (1948) have also shown that, from comparatively few larvae in hybrids involving resistant lines, the number increased approximately by geometrical progression in the crosses involving successively more susceptible combinations. In a test of single-cross hybrids in 1939, hand-infested with 5 egg masses per plant, the numbers of borers per plant, after mathematical adjustment to eliminate the effects of differences in dates of silking, were 3.6 in crosses involving two resistant lines, 5.8 in crosses involving one resistant and one susceptible line, or two partially resistant lines, and 9.4 in crosses involving two susceptible lines.

In a comparison of two single crosses in 1936, it was shown (Patch 1943) that the ratio of the number of borers in a resistant cross to the number in a susceptible cross increased gradually from 38 to 48 per cent as the time between borer hatching and pollen shedding decreased from 38 to 14 days, and then increased sharply to 86 per cent as the interval decreased to 2 days.

In a comparison in 1934 of three borer-resistant inbred lines with three borer-susceptible lines, all in single-cross or top-cross combination on common parents the resistant hybrids had 55 per cent as many borers as the susceptible hybrids when planted on May 31, 70 per cent as many when planted on May 17, and 89 per cent as many when planted on May 3. The borers hatched 27, 19, and 11 days before the silking of the three plantings, respectively. Here again, the ratio showed a similar increase with an advance in development of the plants at the time the eggs hatched.

In all the tests hatching took place before the hybrids shed pollen or silked. More recently the multiple-brood strain of the borer has become the dominant form throughout the central Corn Belt. To simulate the second generation of this brood, eggs were placed on the plants by hand early in August, in experiments conducted at Lafayette, Ind., in 1944 and 1945. In these tests some of the eggs hatched while the plants were in the silking stage. The results are reported in this paper. The evidence indicates that differential resistance among strains to the early generation may decrease or disappear by the time the second-generation larvae hatch.

The 1944 Experiment.—Fourteen single-cross hybrids were compared in a planting made on May 28 of plots consisting of six 6-hill rows with 7-fold replication. The pedigrees of six hybrids included inbred lines known to be resistant to the survival of the June generation of borers, 5 hybrids were made up of one resistant and one susceptible line, and 3 hybrids involved susceptible lines. Two rows were subjected to natural infestation only, 2 rows had 3 egg masses placed on each plant by hand, in addition to the natural infestation, and 2 rows had 6 egg masses placed on each plant. The egg masses were obtained in quantity from moths reared in the laboratory. Small disks of waxed paper, each bearing an egg mass, were pinned on the plants just before the eggs hatched. The eggs hatched from August 4 to 11, or from 1 to 8 days after most of the hybrids began to show silks. Eighteen plants from each plot were dissected from September 9 to 26. From 4 hybrids averaging 8.4 borers per plant on September 9, it was determined that on the average 1.45 ± 0.13 per cent of the borers disappeared from the plants each day the dissections were delayed; from 6 hybrids averaging 9.6 borers per plant, 2.17 ± 0.21 per cent disappeared; and from 4 hybrids

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Table 1.—Number of European corn borers per plant in single-cross hybrids of dent corn involving inbred lines known to be resistant or susceptible to the survival of the June generation, 1944.

PEDIGREE OF HYBRID	BORERS PER PLANT			DAYS AFTER JUNE 30 UNTIL PLANTS SILKED[1]
	Natural Infestation	3 Egg Masses per Plant in Addition	6 Egg Masses per Plant in Addition	
Resistant Group				
Ill. R4×Kan. K230	1.9	6.6	9.5	34.0
Ill. R4×Ia. L317	2.0	8.1	10.2	34.4
Ind. P8×Ia. L317	1.5	7.6	10.6	36.7
Ind. P8×Ia. L304A	1.5	7.6	11.6	33.0
Ind. P8×Ill. R4	2.2	8.4	11.6	34.6
Ind. P8×Kan. K230	2.1	9.1	13.0	34.0
Mean	1.9	7.9	11.1	34.5
Partially Resistant Group				
Ind. WF9×Kan. K230	1.9	7.0	9.3	30.9
Ind. WF9×Ill. R4	1.2	7.0	9.9	32.3
Ind. WF9×P8	1.5	7.4	10.1	32.9
Ill. R4 ×C.I. 187-2	1.9	8.0	10.1	33.9
Ind. WF9×Ia. L317	1.4	7.2	10.4	34.0
Mean	1.6	7.3	10.0	32.8
Susceptible Group				
Ill. A×Ind. WF9	1.4	7.7	9.1	30.9
Ill. A×C.I. 187-2	1.4	11.2	12.2	33.9
C.I. 187-2×Ind. WF9	1.4	8.9	12.6	33.6
Mean	1.4	9.3	11.3	32.8

[1] Eggs hatched from 35 to 42 days after June 30 or from 1 to 8 days after the mid-silking date of 9 of the 14 hybrids.

averaging 12.2 borers per plant, 2.68 ± 0.20 per cent disappeared each day between September 9 and 26. On the basis of these data the number of borers in the plants on September 9 was estimated for each hybrid. Since observation showed a very low level of natural infestation of the June generation of borers, these estimates were almost wholly of the August infestations. The estimated numbers of borers per plant on September 9 for each level of infestation are given in table 1.

As an average of the 3- and 6-egg-mass levels in table 1 the resistant group contained 9.5 borers per plant, as compared with 8.7 and 10.3 borers in the partially resistant and susceptible groups, respectively. The resistant group silked later than the other groups, but data are not adequate to show the effect this might have had on the above averages. If the hybrids are taken regardless of group, the five hybrids silking earlier than 33.1 days after June 30 averaged 8.7 borers per plant, as compared with 9.7 borers in hybrids silking later than that time. Three of the five earliest silking hybrids were in the partially resistant group, a fact which may explain the lower borer populations in that group. In this experiment the resistant group averaged nearly as many borers as did the susceptible group.

THE 1945 EXPERIMENT.—A commercial hybrid, Ind. 610B, with pedigree (WF9×Hy)×(A×L), and hybrid Ind. P8×Ia. L317, an experimental single cross, were compared. Hybrid P8×L317 was chosen for the test because both the inbreds P8 and L317 had shown resistance in previous tests. Ind. 610B was used because the borer-susceptible inbreds WF9 and A and partially resistant inbreds Ill. Hy. and Ill. L assured a fair degree of susceptibility to borer survival in this hybrid.

The hybrids were planted on 5 dates in 2 series of 2- by 2-hill plots with 6-fold replication. The hills, 40 inches apart each way, were thinned to 3 plants each. Two hills in each plot of one series were infested by hand from June 28 to July 2 with 6 egg masses per plant, and 2 hills in each plot of the other series were infested on August 9. The 2 hills remaining in each plot were infested naturally, except for the migration of young wind-blown larvae within the plots.

During the second week of August, samples of 24 plants were dissected to count the borers of both the naturally infested

Table 2.—Numbers of European corn borers surviving on two dent corn hybrids in relation to time between hatching of eggs and silking of plants, 1945.

Date of Planting	Days Eggs Hatched Before (+) or After (−) Silking of Plants[1]	Number of Borers per Plant			
		Ind. 610B		P8×L317	
		Natural Infestation	Additional Infestation by Hand	Natural Infestation	Additional Infestation by Hand
		Eggs hatched on June 30			
May 30	+40.5	0.51	0.79	0.33	0.21
21	+36.9	.98	1.19	0.39	0.38
9	+34.2	1.13	1.20	0.70	0.60
April 30	+32.4	1.49	1.33	0.88	0.88
		Eggs hatched on August 9			
June 11	+ 7.0	1.20	11.15	3.60	8.20
May 30	+ 0.5	.87	12.80	1.61	9.20
21	− 3.1	1.00	11.75	1.94	11.25
9	− 5.8	.73	7.70	2.33	9.25
April 30	− 7.6	.89	10.10	2.31	9.40

[1] Average of hybrids Ind. 610B and P8×L317. Hybrid Ind. 610B was 4.5 days earlier in silking than P8×L317.

and the hand-infested plants of the June infestation, and similar samples were dissected during the third week of September to determine the result of the August infestation of eggs. The remaining plants in the plots provided data on yield as a measure of plant vigor. The numbers of borers per plant from both types of infestation are arranged in table 2 according to the number of days between hatching dates of the eggs artificially placed on the plants and the dates of silking.

The numbers of borers resulting from both methods of infestation with the June generation of eggs are shown in table 2 to be less than 1 per plant on all plantings of hybrid P8×L317 and less than 1.5 per plant of Ind. 610B. Hybrid P8×L317 averaged 0.58 borer per plant from the hills infested naturally and 0.52 borer from the additional infestation by hand. Hybrid Ind. 610B averaged 1.03 and 1.13 borers per plant from the respective sources of infestation. These low levels of infestation indicated an extraordinarily low rate of larval survival and were obtained notwithstanding the fact that the plants were unusually thrifty, Ind. 610B yielding from 101 to 110 bushels per acre and P8×L317 from 104 to 149 bushels per acre. However, P8×L317 averaged about 51 per cent as many borers as Ind. 610B, as was expected.

The borers from the August infestation of eggs applied by hand were much more numerous on all plantings than were those from the natural infestation. From the hand infestations there was an average of 12.0 borers per plant on the 2 latest plantings of Ind. 610B, where the eggs hatched up to 7 days before the plants silked, as compared with an average of 8.7 borers, or 72.5 per cent as many, in P8×L317. On the 3 early plantings, however, where the eggs hatched up to 7.6 days after the plants silked, both hybrids averaged 9.9 borers per plant.

Data in table 2 show also that P8×L317 contained from nearly 2 to 3 times as many borers as Ind. 610B under the natural infestation in August on the different plantings. As an average of all the plantings, these hybrids contained 2.36 and 0.94 borers per plant, respectively. In a test of 112 single-cross hybrids in 1943 hybrid P8×L317 also ended the season with more than the average number of borers. It contained 3.7 borers per plant as compared with 2.8, the number predicted on the basis of the regression of number of borers on the silking date of the hybrids. Since P8×L317 is resistant to the June generation and appears to favor the survival of the August borers about as much as do other hybrids, one may conclude that it had more borers at the end of the season because it received more eggs than Ind. 610B. On the three early plantings, where eggs were laid in quantity, hybrid P8×L317 received from 1.5 to 1.9 times as many egg masses as Ind. 610B, even though the plants of the latter were taller. Tests conducted by R. T. Everly in 1944, and data obtained

by him in 1946, also showed the inbred lines P8 and L317 to be attractive to the moths for oviposition. He found that P8×L317 ranked sixth in attractiveness to the June-generation moths in 1946 in a test of 34 inbred lines crossed on line L317. P8×L317 was also one of the three most attractive hybrids in a test by Morris Schlosberg in 1947 of 22 inbred lines crossed on line L317. Everly & Schlosberg compared the numbers of egg masses laid on the hybrids with the numbers predicted on the basis of the regression of number of egg masses on the height of the hybrids at time of oviposition.

The data as a whole indicate that a hybrid resistant to the survival of larvae of the June generation, hatching when the leaves are in the whorl, may be as susceptible to survival as a susceptible hybrid when eggs of the August generation hatch while the plants are silking. A further conclusion is that, because of their greater attractiveness to moths for egg laying, some hybrids resistant to the survival of the June generation of borers may end the season with more borers per plant than are found on susceptible hybrids.

SUMMARY.—The resistance of different dent corn hybrids to the survival of larvae of the June generation was tested by having egg masses, placed on the plants by hand, hatch at different times with respect to the development attained by the plants. Plant development at time of infestation was varied by planting on different dates and by infesting the plants with eggs at different times.

Data from work reported herein were obtained from hybrids on which the eggs hatched late in June and early in August, before and after the hybrids silked. In 1944 a group of hybrids known to be resistant to the survival of the June generation of borers averaged nearly as many borers per plant as a group of susceptible hybrids when the eggs hatched within 8 days after most of the hybrids silked. In 1945 borer-resistant single-cross hybrid Ind. P8×L317 contained about 51 per cent as many borers as susceptible double-cross Ind. 610B when the eggs hatched in June from 32 to 41 days before the plants silked. Hybrid P8×L317 contained 72.5 per cent as many borers when the eggs hatched in August from 1 to 7 days before the plant silked, but both hybrids averaged 9.9 borers per plant when the eggs hatched from 3 to 8 days after the plants silked.

In 1945 the natural infestations of both the June and August generations on all plantings averaged 0.94 borer per plant in Ind. 610B and 2.36 borers in P8×L317. Supplementary data indicate that the larger number of borers in P8×L317 was due to more than average attractiveness of this hybrid to the moths.

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PROFESSOR METCALF DIES

Prof. C. L. Metcalf, 60, head of the department of entomology, University of Illinois, died August 21 at Urbana. He had been on leave of absence for the past two years because of ill health. He was a former president of the Entomological Society of America and was a native of Ohio.

DDT, Ryania, and Benzene Hexachloride for Control of the Elm Leaf Beetle[1]

F. L. Gambrell, *N. Y. Agricultural Experiment Station, Geneva, New York*

The elm leaf beetle *Galerucella xanthomelanea* Schrank is one of the most serious foliage pests of elm trees in New York. For the past two decades during which the writer has observed it the beetle has been quite abundant. Injury has been serious and widespread on both native and introduced species of elms in many cities, villages and rural areas.

Materials, Methods and Results.—Lead arsenate has been recommended for many years for the control of this insect. Rotenone-bearing insecticides have also been shown to be quite effective (Gambrell 1940). During 1944 it was found that the larvae of the elm leaf beetle were quite susceptible to a DDT spray containing 2.5 pounds of a 20 per cent wettable powder (0.5 pound of DDT) in 100 gallons of water. The material was applied witha power sprayer on June 23. Within 8 hours following application approximately 3000 young larvae and 27 adults were collected on a cheesecloth strip 12 by 18 feet in area which was placed under one-half of a small American elm which was sprayed with the above mixture. No further foliage injury from larvae was observed following this application.

Following these observations another American elm, approximately 24 feet tall, was sprayed on July 28, 1944 to obtain information on the effect of DDT upon adults which had recently transformed from the pupal stages. The mixture contained 2.5 pounds of a 20 per cent DDT wettable powder and 4 fluid ounces of a spreader[2] in 100 gallons of water. Cheesecloth strips were placed under the entire tree prior to spraying so as to recover any beetles which fell from the tree. Adults began falling from the sprayed tree within a few minutes after application. Most of these beetles were unable to fly and displayed characteristic symptoms of DDT poisoning. Records on the number of beetles obtained from this tree at various intervals are given in table 1, together with the percentage of dead beetles at the time of collection. In most cases all adults were dead within 48 hours after collection, but in one instance a beetle was still alive 2 weeks later. Records on beetles collected from unsprayed trees for comparable periods showed from 0 to 4 per cent normal mortality. Adults were considered to be alive as long as there was any evidence of movement of antennae, legs or wings. Only small numbers of beetles were collected on the cloth from the sprayed tree after the fourth day following treatment as compared with large numbers of adults present on nearby unsprayed trees. It is the opinion of the writer that most, if not all, of the beetles collected from the cloth after the first few days following treatment apparently migrated into the sprayed trees from outside sources. From the data given in table 1 it will be seen that 92 per cent of all the beetles collected were taken within the first 24-hour period following application. Of this number 71 per cent fell within 2 hours after spraying and 84 per cent within the first 7 hours.

Table 1.—Effect of DDT on adults of elm leaf beetle collected on cloth under tree at various intervals after treatment.[1] Tree was sprayed July 28, 1944 at rate of 0.5 pound DDT in 100 gallons water.

Collection of Beetles			Per Cent of Beetles Dead at		
Interval after Spray	No. Collected	% of Total	Time of Collection	24 Hrs. Later	48 Hrs. Later
2 hrs.	1884	65.3	—	99	100
7 hrs.	360	12.4	—	95	100
24 hrs.	403	13.9	60	—	97
3 days	115	3.9	85	90	100
4 days	51	1.7	76	92	94
5 days	19	0.7	63	100	—
6 days	27	0.9	63	97	100
8 days	15	0.5	93	—	100
14 days	10	0.3	80	90	90

[1] Mortality of beetles collected from unsprayed trees ranged from 0 to 4 per cent.

Limited tests were conducted in 1945 in which a 10 per cent DDT-pyrophyllite dust was applied by an explosive charge from a 9-inch cardboard mortar such as that used and described by Glasgow (1944) and illustrated in figure 1. Numerous larvae and adults were collected on cloths placed under treated trees. Leafhoppers

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 756, April 28, 1948.

[2] *Triton B-1956.*

spittle bugs, lady bird beetles and syrphid flies were also affected by the DDT dust. Further beetle injury was prevented for the remainder of the season whereas nearby untreated trees were severely damaged.

In another experiment during 1945 each of three different groups of American elms in three different localities received a single spray of DDT or Ryania[1] (ground roots and stems of *Ryania speciosa*), or lead arsenate for the control of this insect. Materials were applied with a power sprayer at 500 to 600 lbs. pressure per square inch. The first series of trees was sprayed at Pen Yan, N. Y., in cooperation with village authorities. Sprays were applied on June 20 shortly after oviposition began. The second group of trees was sprayed at the Newark Country Club on June 26 about a week after hatching was first observed. The third group, located on the experiment station grounds, was sprayed on July 12 when approximately 50 per cent of the egg masses had hatched and some fully grown larvae were present. The following spray formulae were used per 100 gallons: DDT one pound (2.5 lbs. of 40 per cent wettable powder), sticker-spreader[2] 2 fluid ounces; lead arsenate 4 pounds, soybean flour 1 pound, and hydrated lime 8 ounces; *Ryania* wettable powder 1 and 2 pounds respectively, and a sticker-spreader 2 fluid ounces. During 1946 similar treatments were made at Newark, N. Y. June 19, using the above mixtures. In addition a benzene hexachloride wettable powder, containing approximately 3.8 per cent of the gamma isomer, was applied at the rate of one pound per 100 gallons of water, without additional wetting agent. Approximately 60 per cent of the egg masses had hatched at the time the treatment was made and numerous first and second instar larvae were present. The relative toxicities of these treatments for both 1945 and 1946, as based on larvae recovered, are summarized in table 2. In another test located at Geneva, heavily infested American elms 50 to 70 feet tall were thoroughly sprayed on June 7, 1946, with DDT, *Ryania* or lead arsenate at the rates indicated above. Overwintering beetles were very actively feeding on the new foliage (Fig. 2); some eggs had been deposited but hatching was not observed until June 13. Within 24 hours after application hundreds of beetles were observed on the ground under the trees sprayed with *Ryania* and DDT. This single application gave excellent protection against further adult feeding and prevented larval injury.

Limited information was also obtained on the effect of DDT when applied as an aerosol fog. On August 6, 1945 a Chinese elm approximately 30 feet tall was thoroughly treated with a fog applicator (Fig. 3) using a 5 per cent DDT-fuel oil solution at the rate of 2 gallons (12 oz. technical DDT) per tree. This proved to be a very heavy application. Cheesecloth strips were placed on the ground under both treated and untreated trees and adults and larvae were collected at various intervals following application as indicated in table 3. From these records it will be

Table 2.—Toxicity of DDT, *Ryanex*, benzene hexachloride and lead arsenate sprays to larvae of the elm leaf beetle. All sprays were applied on large trees with a power sprayer.

Treatment	Concentration (actual toxicant)	Per Cent Larvae Dead, Days After Treatment 1945			1946	Per Cent Eggs Containing Dead Larvae
		1	6	14	10	
DDT[1]	1 lb.—100	39	100	94	99+	10
Ryania[2]	1 lb.—100	—	—	—	60	9
Ryania	2 lb.—100	10	18	90	—	—
Benzene hexachloride[3]	1 lb.—100	—	—	—	80	39
Lead arsenate	4 lb.—100	5	37	99	52	3
Check	—	0	1	1	2	3

[1] Wettable powder.
[2] Special spray grind form.
[3] Containing 3.8 per cent gamma isomer.

[1] *Ryanex.*
[2] *Grasselli.*

observed that large numbers of adults and larvae were collected from the cloth under the treated tree on August 7, 18 hours after application, whereas relatively few specimens were taken from the cloth under a heavily infested but untreated tree which was located some 50 feet away.

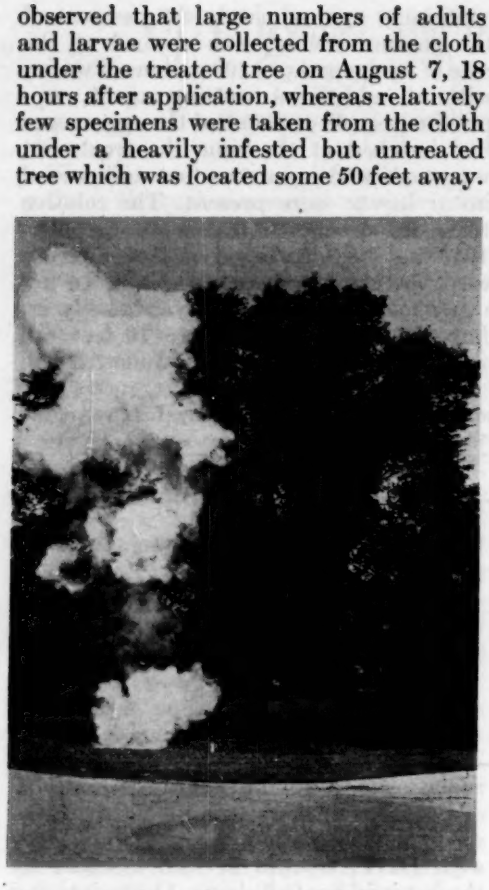

FIG. 1.—Applying a 10 per cent DDT dust by an explosive charge from a cardboard mortar. Unexploded mortar located on ground to right of dust.

At the time of application numerous adults were observed to fly out of the tree. Many of these beetles returned but others apparently flew to surrounding trees. This observed flight at time of application coupled with later movements of adults, may also be reflected in records obtained from the untreated tree located nearby.

Table 3.—Effect of DDT—fog treatment on elm leaf beetle—Applied at 6:00 P.M. August 6, 1945.

Treatment	Collected Under Tree			Per Cent Dead	
	Date	No. Adults	No. Larvae	Adults	Larvae
DDT—Fog	8/7	240	2800	100	79[1]
	8/11	58	53	81	36
Check	8/7[2]	14	52	29	0
	8/11	4	4	0	0

[1] 99 per cent of larvae were dead 5 days after treatment.
[2] Check tree was approximately 50 feet away from treated tree but may have received some drift during application.

FIG. 2.—Severe foliage injury caused by feeding of overwintering adults during the preoviposition period.

Some yellowing and falling of leaves resulted on the portion of the tree which received an excessive amount of fog.

On June 6, 1947 two large American elms were treated with the fog machine[1] using a 20 per cent solution of DDT dissolved in a 50 per cent mixture of oil[2] and carbon tetrachloride. This material was applied at the rate of 1 gallon of the mixture per tree, or approximately 24 ounces

FIG. 3.—Applying a 5 per cent DDT-fuel oil mixture with a fog applicator.[1]

[1] *Todd Insecticide Fog Applicator.* Manufactured by Todd Shipyards Corp., New York, N. Y.
[2] Socony-Vacuum Gap, PD-544C.

of technical DDT. The machine was set to operate at between 30 and 60 microns. In 1947 preliminary tests were also conducted with a parathion spray in which the 15 per cent wettable powder was used at the rate of 6 pounds per 100 gallons. This was applied with a power sprayer at 600 lbs. pressure. Adults, which were present in large numbers, were killed within a few hours following treatment; also excellent control was obtained on both young and full-grown larvae. Most of these larvae were affected within a few hours and fell from the leaves to the ground.

In 1947 opportunity was also afforded to follow extensive elm leaf beetle control spray operations in the village of Penn Yan and the city of Hornell where a DDT spray, containing 2 pounds of 50 per cent wettable powder in 100 gallons of water, was applied using municipal-owned equipment. In one instance a *sticker-spreader* was used with the DDT at the rate of 2 fluid ounces per 100 gallons while in the other case no wetting agent was used. A total of approximately 7000 trees was sprayed with DDT in this manner. Officials in charge of these spray operations indicated that they were quite satisfied with the results obtained. Neither reported any complications with red spider or aphids following the use of DDT under their conditions.

SUMMARY.—The toxicity of DDT to adults over a period of two weeks in the field is shown in table 1. These records together with numerous other field observations show that both adults and larvae are quite susceptible to DDT when applied as a wettable powder in spray form, DDT-pyrophyllite dust by explosive mortars and DDT-fuel oil solutions with the *fog applicator*. The rate of knockdown and kill of larvae with DDT, as seen in table 2, was much more rapid than it was with *Ryanex*, benzene hexachloride or lead arsenate. DDT compares favorably with derris and cube powders in this respect. Adults appeared to be affected more rapidly by DDT than did the larvae. Both DDT and *Ryanex* knocked down first, second and third-instar larvae but the older larvae appeared to die more slowly than did small first-instar larvae. Benzene hexachloride was less rapid in its action on larvae than was DDT, but quite effective in killing many young larvae still in the egg shell just as they were hatching, thus suggesting a fumigating effect. One application of benzene hexachloride applied during the egg hatching period afforded satisfactory protection for the remainder of the growing season and no foliage injury was observed. DDT, *Ryanex* and benzene hexachloride show definite promise in experiments for the control of adults and larvae of the elm leaf beetle but further tests are needed to evaluate fully these materials before their use is generally recommended.—5-13-48.

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Dr. Fabian Garcia, for more than thirty years Director of the New Mexico Agricultural Experiment Station and Head of the Horticulture Department, died in Las Cruces, New Mexico, August 6, 1948. Since a number of Dr. Garcia's early publications were concerned with investigations of fruit and vegetable insects a more complete account of his life will appear in the JOURNAL in the near future.

Insect-Problems in Corn Processing Plants

GEORGE E. GOULD, *Purdue University, Lafayette, Indiana*

The insect population of corn processing plants has received little study and as a consequence the species involved and the extent of the infestation is not fully known. During the war years plants were operated at maximum production and little attention was given to the routine matters of sanitation and pest control. In the past few years the leaders of the industry have become increasingly aware of their insect problems and the danger of possible contamination of food products. Therefore to determine the insect population of typical plants and methods of checking and preventing the increase of pests, a thorough inspection[1] was made of two plants (both in Illinois)—one in July of 1945 and one in April of 1946. This survey revealed a total of 55 species of insects and mites that were inhibitants of such plants. Many of them are well known as pests in flour mills, while others are previously unreported as injurious to or inhabitants of cereal processing plants.

The insect pests attacking grains, either whole or in the ground condition, are for the most part common to both wheat and corn. However, in the processing of corn into starch a new environmental factor, moisture, is introduced and this accounts for many of the pests distinctive to the corn processing industry. The moist environment in the buildings of the wet starch division create conditions favorable not only to pests of the corn but to those associated with the abundance of moisture and food. The actual loss caused by insects feeding on the grain is negligible, but the potential hazard of insect fragments in food products is of utmost importance.

In the processing of corn many pests, such as weevils, grain moths and flour beetles, can be brought into the storage in or on the grain. The initial cleaning process for the removal of dirt and plant debris also removes many of these insects, while the second step, the grinding and steeping of the corn, destroys the remainder. In this process of steeping and grinding, however, an entirely new environment, an environment of moisture and heat in the presence of food, is created. This favorable environment continues through the next two steps, the separation of the germ from the kernel and the separation of the starch from the gluten. The gluten and other waste products are sent to the feed division where they are subjected to high temperatures in the preparation of livestock feed. The starch continues on into the dry division where it is processed, purified and eventually manufactured into such products as laundry starch, edible starch, dextrose and corn syrup.

The insect populations of the two plants were, in general, identical except for certain winged forms, such as the housefly, that were common only in July. Since the two populations were so similar, it can be assumed that other processing plants have much the same problems as these two. This conclusion is further substantiated by reports of commercial pest control servicemen and the sanitary engineers of other plants. The insects listed here do not comprise the complete list of possible pests, but probably include the most troublesome invaders. The notes included below with each species are from observations in the two plants and from published information about them. The insects listed here have been identified for the most part by the taxonomic specialists of the U. S. Bureau of Entomology and Plant Quarantine.

DERMAPTERA.—1. *Euborellia annulipes* (Lucas). The ring-legged earwig. Of all the insects found in corn processing plants this species was the most unusual and perhaps the most numerous. It was abundant in the table house of the wet starch division and could be found in any building where water and starch were associated together. In the table house where the wooden tables were saturated with moisture and frequently covered with starch, these insects could be found under boards and in cracks of all kinds. They were rather sluggish, wingless insects, but managed to disappear with amazing swiftness when disturbed. They fed apparently on starch, as A. F. Bucholtz (in a mimeographed article dated

[1] These inspections were made possible through the cooperation of the late Walter S. McCloud of W. B. McCloud and Company, Chicago.

December 17, 1945) states that he has been able to rear the young on starch. All stages, eggs, nymphs and adults, were found together in most locations.

Earwigs in general are considered rather rare insects in the north-central states and are usually associated with decaying organic matter in damp situations. Because of their habits and their preference for damp locations they have been spread throughout the world by commerce. The ring-legged earwig was first found in this country in Mississippi in 1884. Unpublished records of the species include specimens from corn processing plants in Indiana, Illinois, Iowa and Missouri, from breweries in Missouri, and from an abattoir in Indianapolis.

This earwig is known to be predaceous and in Hawaii is an aid in the control of the sugar cane leafhopper (Swezey 1946). In years when this leafhopper was abundant the earwig fed almost exclusively on that pest. Pallister (1927) found this earwig abundant under lights at Mobile, Alabama, where it was feeding on various insects attracted there. Lyle (1937) in Mississippi reported damage to sweet and Irish potatoes in storage, while Klostermeyer (1942) in Nebraska observed it feeding on grain and to some extent on stored grain insects, and Smith (1943) in Kansas reported it common in flour mills. In Ohio, Neiswander (1944) reported serious damage to roots of vegetables grown in greenhouses.

This earwig is not a new pest in corn processing plants as it has been known in some for about 25 years. The workmen in the plant usually refer to them as "starch bugs" as they are commonly associated with the wet starch division.

COLEOPTERA.—*Tribolium confusum* (Duval). Confused flour beetle. This beetle along with the following six are frequently grouped under the title of "flour beetles" or "bran beetles." It is a very common and widespread pest of cereal products, although it feeds only on broken or ground grain. This beetle was found in small numbers in numerous locations where quantities of dry starch were allowed to accumulate. In our laboratory at Purdue samples of four different starches and two soybean flours were stored for several years. One sample of starch and the soybean flour with 20 per cent oil content became heavily infested.

Oryzaephilus surinamensis (L.). The saw-toothed grain beetle is found in the same locations as the preceding but is not as common.

Laemophloeus pusillus Schon. The flat grain beetle is reported as primarily a scavenger associated with other food products pests. In one plant it was more common than the confused flour beetle.

Laemophloeus punctatus Lec. Members of this genus have been taken in the spring at sap on maple and beech stumps. It was found associated with the above species in the plant.

Laemophloeus ferrugineus (Steph.). The rust-red grain beetle a common species found in stored grain and other foodstuffs but is considered to be mainly a scavenger.

Ahasverus advena (Waltl.). The foreign grain beetle is of minor economic importance and is attracted to damp and moldy grain, where it feeds on the molds, fungi and dead insects that occur in grain.

Silvanus bidentatus (Fabr.), has been reported from flour.

Tenebroides mauritanicus (L.). The cadelle is a common pest of stored grain, although in this survey only two specimens were found.

Tenebrio molitor (L.). Both the yellow mealworm and the following species are common pests of grain in storage. Specimens of the two were not found, but the description of "worms" living in spilt corn outside the elevator indicated that either one or both species occurred around the plant.

Tenebrio obscurus (Fabr.). The dark mealworm.

Alphitobius diaperinus (Panz.). The lesser mealworm, and the following four species are frequently called fungus beetles. This species feeds upon damp and moldy grain, milled products and spoiled foods.

Alphitobius piceus (Oliv.). Black fungus or grain mold beetle. This and the preceding species were frequently found around starch plants. Numerous beetles and larvae were found in the sloppy accumulations near the pile of old clothes used on the gluten presses. Specimens were also found in the feed warehouse.

Carpophilus dimidiatus (Fabr.). The corn sap beetle was found in this survey in damp locations along with the follow-

ing species.

Carpophilus nitens Fall. This fungus beetle was found in numerous locations around buildings in the wet starch division. On a ledge above the starch separation table, in the table house, starch and dirt had accumulated. In a piece of this damp material about 2 inches square and an inch thick a total of 75 beetles, larvae and pupae were found. In decaying wood along the edge of the tables it was frequently associated with earwigs, ants, mites, springtails and the German roach.

Carpophilus hemipterus. (L.). Dried fruit beetles were taken in both plants.

Mycetophagus bipustulatus Melsh. This fungus beetle was found in one plant.

Hypophleous sp. A single specimen was collected.

Agonoderus pallipes Fabr. Seed corn beetle. This ground beetle was common on the ground floor of the soybean oil extraction plant, where it was found in fermenting debris accumulating beside a grinding machine.

Philonthus sp. Numerous specimens of Staphylinid beetles were observed in the same area as earwigs. At first, because of its shape and size, it was confused with the earwig, but when disturbed it would fly out the windows. The ring-legged earwig is wingless.

Ptinus fur (L.). The white-marked spider beetle was found on a bag of feed in a warehouse.

Pagiocerus sp. probably *frontalis* (Fabr.). Specimens of this weevil were taken from shipments of corn from South America. W. H. Anderson of the Bureau of Entomology and Plant Quarantine reports that this species is commonly intercepted in corn shipments from South America and that this, or a closely related species, occurs in South Carolina, Georgia and Florida.

Sitophilus granarius (L.). Granary weevil. This pest was found in one of the two plants inspected.

Sitophilus oryza (L.). The rice weevil was found in a lot of corn from South America.

Dermestid larvae. The larvae of at least two species of this family were found feeding on cereal products. A sample of soy flour with high oil content was heavily infested with one type of larvae. In cracks along the floor of a feed-bagging room two species were found. They were not reared.

DIPTERA.—*Musca domestica.* The housefly was found in both plants but was more abundant during the survey made in July. It was common in many of the buildings but never excessively abundant.

Calliphora spp. Blow or blue-bottle flies were present in both plants with the larger population in July.

Drosophila funebris (Fabr.). The vinegar gnat was common in both plants and was the most serious insect problem in one. They were apparently attracted to the fermenting materials around overflow areas or seepage from starch vats and troughs. Clouds of the gnats hovered around suitable moist areas where the larvae could be found in damp accumulations of starchy materials. Maggots were difficult to find, but the brown puparia could be seen in large numbers in the adjacent dry areas.

Telmatoscopus albipunctatus (Will.). This moth fly was found in standing water near a basement wall of a storage building.

Leptocera sp. This small fly was found in both plants.

Scatopse notata (L.). This minute species was found in one plant, while the following species was found in the other.

Scatopse fuscipes Mg.

Platypalpus sp. Members of the family Empididae are predaceous and their larvae may occur in water.

Empis sp. This and the above species were found in the same plant.

Lonchaea sp. The fly was a newly emerged individual and could not be identified to species. Members of this genus are reported as sap feeders in the larval stage.

Dasyhelea sp. The larvae of this group are aquatic and have been reported from algae of ponds.

Toxomerus marginatum (Say). This syrphid fly probably entered the table house through an open window.

HYMENOPTERA.—*Aphidius testaceipes* (Cress.). This small Braconid parasite of aphids probably entered the building through an open window.

Monomorium pharaonis (L.). Workmen around the plants report ants to be one of the major insect pests of the building where corn syrup is refined and packaged. During two inspections no ants could be found in the syrup refining buildings and

only a few in the entire plant. These were in the wet starch division and did not appear to be attracted there by the starch.

Pheidole sp. The big-headed ants were in the same buildings as the above species.

LEPIDOPTERA.—*Pyralis farinalis* (L.). The meal snout moth was found in a small room in the feed warehouse. A few live and many dead moths were caught in the spider webs in this room.

ORTHOPTERA.— *Blatella germanica.* (L.). The German roach was one of the four most abundant species of insects found in both plants. Roaches were widely dispersed and could be found in many of the buildings. The wet starch division was heavily infested, especially the under side of the starch separation tables. These tables were of wood and were saturated with water and starchy materials. In the one plant a new procedure in the sanitation program was to treat tables, floors and walls with steam under pressure. This treatment had perhaps killed many roaches and eliminated many safe hiding places, but it had also dispersed them to new areas and other buildings. Another common hiding place was the locker rooms where the men left their clothing and lunch boxes.

Periplaneta americana. (L.). The American roach was common in most of the buildings, especially in basements. It was not as common as the German roach and only around the gluten presses was it seen in any numbers.

Blatta orientalis (L.). A few specimens of the oriental roach were seen in basements, but they were not common.

COLLEMBOLA.—*Achorutes armatus* (Nic.). This springtail is a pest of mushrooms and also attacks fern roots, narcissus bulbs, bean seeds and seedlings, peas and sugar beets. It and the following species were commonly found on standing water in the wet starch division. They were never abundant, but most damp areas and stagnant pools of water had several.

A. tullbergi Schaffer
Entomobrya sp.
Seira plotani (Nic.)
Lepidocyrtus cyaneus var. *cinereus* Folsom

ACARINA.—*Tyrophagus lintneri* (Osb.). This mite is frequently a serious pest in mushroom houses. This and the following species of mites were abundant in the wet starch division and constituted one of the more serious pest problems in both plants inspected. Mites were especially abundant around the grinding equipment in the mill house and the troughs and table ends in the table house. They were commonly found under a layer of starch and gluten deposited by the splashing of these materials from the nearby trough or table. Several species were often found together and were difficult to dislodge by flushing, as they were protected by the starchy deposit.

Caloglyphus moniezi A. Z.
Caloglyphus rodionovi A. Z.
Rhizoglyphus echinopus (F. & R.)
Uropoda sp.
Seilus sp. A predaceous mite
Parasitus sp. A predaceous mite

The above list includes the various insects and mites collected in the two corn processing plants. This list is by no means complete, but does include many of the pests normally encountered in such buildings. Many species present in small numbers were undoubtedly missed, as were many of the winged migrants that occasionally fly in through open windows and doors. The windows of some buildings, such as the table house, are unscreened and are open most of the year. On the other hand, windows and doors of those buildings where the finished products are processed and packaged are tightly screened.

The major pest insects of corn processing plants are five in number: earwigs, mites, vinegar gnats, German roach and fungus beetles. In addition, the pests common to grain and its processing are to be expected but do not represent potential hazards as do the five insects peculiar to the wet processing of corn. Earwigs thrive in the moist environment and the abundance of food found in the wet grinding of corn and the separation of starch and gluten. This insect is not readily controlled by any of the usual methods used against roaches while the use of poisonous insecticides around the starch tables is not advisable because of possible contamination of food products. Fumigation of the table house is impractical as the building is large and not tightly constructed. Future plans at both

plants include the remodeling of equipment to eliminate certain wet areas favorable to these and other pests.

Mites were found in most moist areas about the plants and were often under a layer of starch. They did not occur on the tables and troughs regularly flushed with water but were found in nearby cracks and in equipment where cleaning was difficult. The new method of sterilizing with steam under pressure was eliminating many mites.

Vinegar gnats were common in both plants but were especially abundant in the one where seepage of solutions through troughs and poor pipe connections was observed. The larvae lived in wet areas similar to those infested with mites except that less starchy material was evident where the larvae were living. For control, the elimination of seepage and a thorough treatment of all infested areas with steam once a week was suggested.

Roaches, especially the German roach, were common in the plants and were found in many buildings. Their complete elimination would be difficult as they infested a large area in most of which insecticides must be used with care to avoid contamination of food products.

Fungus beetles were not too abundant, but because of the numerous species involved and the abundance of food suitable to them, they are a potential hazard to food products. They breed in accumulations of gluten and starch and could be checked by frequent, thorough clean-up of equipment and buildings.

SUMMARY.—Of the 55 species of insects and mites collected during the inspection of two corn processing plants, none was causing serious damage to the grain and the products made from grain but several were potential hazards to the production of pure foods. The insect population in these plants consisted not only of the common pests of stored and processed grain but also a number of insects attracted to the moist environment peculiar to starch manufacturing plants. Only five, the earwig, mites, the German roach, the vinegar gnat and fungus beetles, were present in any numbers. Present control measures have held most pests in check, but the control of certain insects will necessitate a thorough sanitation program and the repair and replacement of certain old equipment.

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Dr. Theodore Dru Alison Cockerell, nationally known as an outstanding teacher of entomology and an authority on the taxonomy of bees and scale insects, died at San Diego, California, January 26, 1948. Although primarily a taxonomist, Dr. Cockerell published many interesting observations concerning the habits and control of injurious species of insects, particularly those of the Rocky Mountain Region. A biographical sketch will appear in this JOURNAL at an early date.

Transplantation of *Hypoderma* Larvae and Testing Chemicals for Control of Larvae in Experimental Hosts

W. L. Barrett, Jr., and R. W. Wells, *U.S.D.A. Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Cattle grubs, *Hypoderma lineatum* (De Vill.) and *H. bovis* (Deg.), parasites of cattle, cause great losses of milk, meat, and leather over almost the entire United States. Various authorities have estimated such losses to be $65,000,000 to $300,000,000 each year.

This paper discusses some of the disadvantages of external application of insecticides to cattle for grub control and presents the methods used in transplanting first-instar *Hypoderma* larvae from slaughtered cattle to goats, rabbits, and mice; data on survival of the larvae; and the methods used in testing chemicals *in vitro* and *in vivo*. Preliminary experiments were conducted at the Dallas, Tex., laboratory (now at Kerrville, Tex.) of the Bureau of Entomology and Plant Quarantine in 1946 and 1947 to develop an internal treatment that would be more satisfactory than the prevailing method of treating grubs seasonally in the backs of cattle.

Larvicides, if applied promptly and repeatedly to the backs of cattle after the larvae perforate the skin, give distinct reductions in the cattle grub abundance. In some of the smaller foreign countries, where herds of cattle are small and are readily handled, this method will undoubtedly suffice for eradication. Such a method is applicable only after the grubs have perforated the skin on the backs of the animals, a damage of importance on cattle that are to be slaughtered soon. Since not all the grubs are present in the back at any one time, successful control with this method requires that applications be made at definite intervals, rather than when the weather is favorable, or when the operation can be coordinated with other ranch operations. For utmost effectiveness the applications should be repeated at 20-day intervals as long as grubs are in the backs of the animals. In a number of the Northern States, where *Hypoderma bovis* is prevalent, this period is as long as 5 months.

The practicability of such a rigid and prolonged schedule is doubted by many of the ranchmen in some of the northwestern states, where cattle are released in boundless pasture lands in the mountains each spring before all the grubs have reached the backs of the animals. On many ranches in the South and Southwest it is not feasible to round up the cattle promptly to meet a definite, necessary schedule of repeated treatments. Some of the pasture lands are so densely wooded that, in the words of a ranchman, "We would have to prowl those pastures four or five times to be sure that we had found every animal." This is a significant statement when one is referring to pastures of several thousand acres.

Definite and continued progress in eradication requires that counties, once freed of grubs, be kept free. Such freedom is complicated, because for 8 or 9 months of the year the grubs in the cattle exist internally and are not visible except in slaughtered cattle.

Such are the problems that arise when attempts are made to eradicate grubs merely by the external application of insecticides. It is apparently urgent to search for an insecticide that is tolerable internally to cattle, and effective in one treatment against the larvae before they reach the back. After qualified treatment, migrant cattle could be certified as grub-free. Cattle could also be freed from grubs before they are sent to mountain pastures. Furthermore, such a treatment could be used at any time during the year when it could be coordinated with other ranch operations, or when weather is favorable.

The use of insecticides by internal medication for the control of insect and arachnid parasites of animals has been investigated very little; yet it holds the promise of being the most satisfactory solution to many of such parasite problems. The situation that has existed until recently was aptly expressed in 1937 by E. C. Cushing, of the Bureau of Entomology and Plant Quarantine, as follows (unpublished report):

"It is believed that the failure to follow this line of research has been due to purely hypothetical inference that any chemical introduced into the body of an infested animal in sufficient quantity and toxicity to destroy the insect parasite would be harmful to the host. Such a hypothesis has no basis in fact for the simple reason that it has never been subjected to thorough-going experimental research."

Only during the last several years has a successful start been made by entomologists in chemotherapy investigations (Roark 1946). Lindquist *et al.* (1944) were able to kill bed bugs and stable flies by administering DDT and pyrethrum extracts internally to rabbits on which the insects were allowed to feed. In 1946 Knipling *et al.* (1948) performed successful chemotherapy experiments at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine.

EXPERIMENTAL ANIMALS AND METHODS.—In the experiments described here, cattle were not used as hosts because of the expense involved. Moreover, many of the chemicals to be tested were not available in amounts required for such large animals. Goats, domestic rabbits, and white mice were tested as hosts. It was essential to determine experimentally that the tissues of the host animal were favorable to transplanted larvae, and that the larvae in the adopted host could be recovered readily for examination.

Bishopp *et al.* (1926) transplanted *Hypoderma* larvae from slaughtered cattle into rabbits, goats, and other animals, and reviewed the earlier similar efforts of other workers.

In the present work 30 Spanish goats were infested with first-instar larvae of *Hypoderma lineatum*. The larvae were removed from cattle gullets and transplanted directly into the subcutaneous tissue of the goat, on the thigh or shoulder. An incision about an inch long was made in the skin, and below the incision a probe was used to open a pocket about an inch in diameter for reception of the larvae. The incision was closed with sutures. Usually 25 larvae were implanted in each goat but several of the animls received as many as 100. Goats appear to be highly resistant to infection and the incisions in all 30 animals healed quickly with no evidence of serious infection.

At intervals up to 4 months after the larvae were impanted goats were slaughtered and examined for larvae. Not more than five larvae were found in any one goat. In one goat only one larva was found. No larvae were found in muscle tissue; all were recovered from areolar connective tissue. In one goat a larva was found about 2 inches from the heart just outside the pleural cavity. In another goat two larvae were found near the gullet 4 months after the larvae had been implanted. None of the larvae had reached full growth.

Some larvae that hatch from eggs deposited by a fly on the hind leg of a goat may reach the gullet of the goat in less than two months. On March 20, 1946 E.W. Laake and the authors obtained ovipositions on the legs of two goats by a captured fly. On May 15, 1946 one of these goats was slaughtered and one larva of *Hypoderma lineatum* was found in the submucous connective tissue of the gullet about midway of the length. The larva was 3 to 4 mm. long, and was found in a position typical of larvae occurring naturally in cattle.

Rabbits were found to be more satisfactory than goats as experimental hosts. Thirteen rabbits were infested subcutaneously with 9 to 25 larvae from May 8 to June 5, 1946. The rabbits ranged in weight from 2 to 4.5 pounds. The periods between infestation and of necropsy ranged from 5 to 26 days. The data concerned with the infestations are presented in table 1. In some other cases in which the data were not so complete, larvae lived in rabbits for at least two months. Three of the rabbits died from infections that originated in the skin wounds. Later it was found that such infections in rabbits could be largely eliminated by holding the larvae for 30 minutes in physiological saline containing 400 units of penicillin per cubic centimeter before they were transplanted into the rabbit. The larvae were implanted directly from the penicillin medium. All the larvae recovered at autopsies of rabbits were found in areolar-type connective tissue, mostly beneath the skin. It is estimated that young larvae may migrate away from the site of implantation at an average rate of 1.5 inches a day.

White mice were found to be useful as

experimental animals in the chemotherapeutic tests on cattle grubs. During April, May, and June 1947, five first-instar *Hypoderma* larvae were transplanted into each of more than 400 mice. The larvae tended to remain in areolar connective tissue for at least a week after implantation. During the third and fourth weeks many larvae died, and those that survived were frequently found free in the pleural and abdominal cavities. The mice appeared to be irritated by large first-instar larvae. Active larvae were recovered as long as 36 days after implantation in mice. For best results the infested mice should be used 3 or 4 days after implantation.

COLLECTION AND HANDLING OF LARVAE.—Most of the larvae of *Hypoderma lineatum* in cattle are found in the submucous connective tissue of the esophagus, or gullet, within 2 or 3 months after the eggs hatch. When the larvae reach the gullet, they remain there for several months and grow very slowly. Practically all the larvae survive *in situ* within the gullet, under ordinary refrigeration, for as long as 5 days. In general, however, for *in vitro* tests the larvae are used within 24 hours after slaughter of the cattle.

In goats the implantations were made on the thigh or shoulder; in rabbits, on the thigh; in mice, on the side of the abdomen. The hair at the site of the incision was clipped, and the skin was swabbed with alcohol. The needles and cotton thread used for sutures were sterile. No dressings or disinfectants were applied over the wounds, lest the larvae be injured.

In vitro TESTS.—*In vitro* toxicity tests on larvae of *Hypoderma lineatum* were attempted in physiological saline and in normal bovine blood serum. Blood serum was found to be a more satisfactory medium than saline at the concentrations of chemicals tested. Blood was collected in sterile containers, defibrinated, chilled, and the serum separated by centrifugation. The serum was held in a refrigerator until immediately before use. The larvae were washed in several changes of physiological saline, in sterile beakers, before they were placed in the blood serum. From 5 to 20 larvae were placed in a sterilized beaker containing 10 cc. of normal serum. The chemical to be tested was dissolved in acetone or other solvent, and then pipetted into the serum containing the larvae.

The concentration used in the preliminary tests was 100 mg. of chemical per kilogram of medium. The beakers, with contents, were placed in a closed glass

Table 1.—Results of experiments in which first-instar larvae of *Hypoderma lineatum* were transplanted into rabbits, 1946.

WEIGHT OF RABBIT (POUNDS)	DATE INFESTED	NUMBER OF LARVAE IMPLANTED	TIME BETWEEN KILLING OF CATTLE AND TRANSPLANTING OF LARVAE INTO RABBIT (HOURS)	DATE RABBIT AUTOPSIED	NUMBER OF LARVAE RECOVERED FROM RABBIT
3½	May 8	9	5	May 14	5
	10	20	7 to 9	23	9
	13	25	7 to 9	15[1]	Not counted
3¾	21	10	1½ to 2½	31	6
	21	10	1½ to 2½	June 5	6
	24	25	6 to 8	May 26	0[2]
2	24	20	7 to 9	June 5	11
	29	25	4 to 7	May 31[1]	Not counted
	29	25	5 to 8	June 2[1]	Not counted
	29	25	5 to 8	June 4	11
4½	June 2	20	7 to 10	13	9
	4	20	8 to 11	30	17
	5	20	26[3]	17	5

[1] Died of infection on this date.
[2] These larvae were washed through mercuric chloride in physiological saline (1:1000) and were seen to be inactive and evidently dead before implantation into rabbit.
[3] Held over night in refrigerator at about 6° C.

jar containing water to prevent contamination and evaporation. They were held at a temperature of 30°C. for 24 to 48 hours, except for the short periods during which the beakers were placed under the microscope for gross observations on the condition of the larvae. Bacterial contamination in the serum reduced the activity of the larvae and eventually killed them. Inactive larvae, if still alive, can be reactivated by placing them in fresh blood serum. Approximately 200 chemical agents were tested on the larvae *in vitro*.

In Vivo TESTS.—During April, May, and June 1947 numerous substances were tested in more than 400 grub-infested mice. One substance tested, eosine Y, was tolerated by mice at a dosage of 400 mg. per kilogram, and it reached and stained the larvae in loose connective tissue. This substance appeared to have no selective toxicity, but the staining of the larvae proves that it is possible to inject substances that will reach the larvae. It is indicated that water-soluble organic compounds should be tested further in the search for a substance that will be able to reach the larvae and exhibit a selective toxicity.

DISCUSSION.—For screening insecticides and for preliminary tests to determine tolerated dosage levels, rabbits and mice are much more desirable than larger animals. Moreover, the dissection at necropsy for recovery of larvae requires much less time and effort. Although the larvae do not survive as long in mice as they do in rabbits and goats, they remain vigorous long enough for *in vivo* tests with a chemical agent. It is possible to obtain rare chemicals in quantities adequate for use in small animals but not in large animals.

It is doubtful that the results obtained by *in vitro* tests are reliable indices of the possible chemotherapeutic action of a compound *in vivo*.

Evidently progress in finding and developing insectidices for chemotherapeutic control of cattle grubs is dependent on large-scale testing of various chemical agents *in vivo*.

SUMMARY.—In preliminary laboratory tests conducted at Dallas, Tex., it was found that the difficulties encountered in the eradication of cattle grubs *Hypoderma lineatum* (De Vill.) and *H. bovis* (Deg.), could be satisfactorily overcome by the use of a chemotherapeutic agent, with a selective toxicity, that would destroy larvae within the host by one treatment.

Goats, rabbits, and white mice were tested as possible experimental host animals for transplanted cattle grubs, first-instar, taken from the gullets of commercially slaughtered cattle. As many as 20 per cent of the larvae were recovered in some of the goats at necropsy. Some larvae survived in the goats for 4 months.

In rabbits as many as 85 per cent of the larvae were recovered 26 days after they had been transplanted. Rabbits are preferred as experimental hosts because of their size, but are more expensive than mice.

Transplanted larvae in mice remained in connective tissue for more than a week, but there was considerable mortality of larvae during the third and fourth weeks. Mice are especially useful for testing rare and costly chemicals as chemotherapeutic agents because of their small size.

Approximately 200 chemicals were tested on first-instar *Hypoderma* larvae *in vitro* in blood serum, and numerous substances were tested in grub-infested mice. Eosine Y reached and stained the larvae in loose connective tissue. It is doubtful that the results from tests *in vitro* are reliable indices of the possible chemotherapeutic action of a compound *in vivo*.

Sources of larvae and methods of collecting, handling, and transplanting the larvae are given.—7-21-48

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Comparative Evaluations of Insecticides for Cattle Grub Control

DEANE P. FURMAN and JAMES R. DOUGLASS, *Division of Entomology and Parasitology, University of California at Berkeley and Davis*[1]

In considering experimental control methods for cattle grubs, there are three principal avenues of approach to break the chain of infestation, namely, before the larvae successfully penetrate the skin, or while they are migrating through the body, or while they are present in the subdermal tissues of the back.

The first of these methods, of breaking the life cycle before the larvae penetrate the skin, has been attempted several times in the past, with little or no success. Matthysse (1945) and Mills *et al.* (1946) reported on the use of DDT sprays on the legs and underline of cattle. They found the treatment of no value either in preventing the larvae from successfully penetrating the skin upon hatching or in preventing the flies from ovipositing.

Efforts to control the grubs while they are migrating through the body have been relatively few, largely because of the practical difficulties so readily apparent in finding a selective drug or in developing a specific effective immunity to the larvae.

The third method, that of killing the larvae while they are in the subdermal layers of the back, has the inherent disadvantage that the pests have already done most of their damage to the host concerned; however, this is outweighed by the fact that it is at this stage of the life cycle that the chain of infestation is most easily broken. It is obvious that the destruction of most of the grubs before they drop from the back, if done systematically over an area, will result in few adult flies to gad the cattle later in the season.

Unfortunately in practice control of grubs by sprays, washes or dusts applied to the backs is seldom 100 per cent effective. At the present time conflicting recommendations exist in the literature, and furthermore several of the newer insecticides are being advanced as effective agents for the control of grubs without adequate evidence of their real value.

The purpose of these experiments is to evaluate certain of the currently recommended cattle grub spray formulae as well as some of the more promising new chemicals. Since it is now known (Douglas & Furman 1947) that both the northern and common species of cattle grub are abundant in California, it was also considered desirable to compare the relative susceptibility of these two species, in both the fifth and fourth larval stages, to various larvicides.

METHODS AND MATERIALS.—The animals treated in these tests were range beef stock carrying light to moderately heavy infestations of either one or both species of cattle grubs. All materials were applied as sprays at a pressure of 350 to 400 pounds. The animals were restrained in chutes while being treated or examined. A nozzle was used which produced a flat, fan-shaped driving spray. In actual operation the nozzle was held about 12 inches from the back of the animal and directed against the "lie" of the hair, using an average of about two quarts of spray per head.

Three to 6 days after treatment the animals were examined and the grubs manually expressed from the cysts. Upon expression the grubs were immediately divided into live and dead categories, following which they were taken to the laboratory for a detailed examination on the same day. Here they were warmed and observed under the dissecting microscope where they were definitively separated as to life and death, species and stage.

The materials used were as follows:

1. Rotenone sulphur mixture containing 10 pounds of 5 per cent rotenone, 10 pounds of wettable sulphur, 1 pint diglycol laurate,[2] 100 gallons water.
2. Rotenone mixture containing 10 pounds of cube of 5 per cent rotenone concentration and 100 gallons water.
3. Rotenone mixture containing 7.5 pounds of cube of 5 per cent rotenone concentration, and 100 gallons water.
4. Eight pounds of 50 per cent wettable benzene hexachloride mixture con-

[1] The authors gratefully acknowledge the aid of Jerzey Neyman, Director of the Statistical Laboratory at the University of California, in setting up the type of analysis to be used; however, the authors accept sole responsibility for the conclusions reached.

[2] Glyco Products Co. Inc.

taining 5 per cent gamma isomer plus 100 gallons water.

5. Five pints of a liquid rotenone extract containing 2.5 per cent rotenone, plus 100 gallons of water.
6. Four pounds of 50 per cent wettable chlordan to 100 gallons of water.
7. One gallon of a 45 per cent emulsifiable concentrate of chlordan to 100 gallons of water.

DISCUSSION OF RESULTS.—The data obtained from these experiments are summarized in table 1. For comparative purposes the data have been so presented as to show relative kills of fourth and fifth stages of each species. In all instances, even with the most effective materials the degree of mortality obtained left much to be desired. In samples of significant size the best kill (64 per cent) was obtained with formulae 1 and 2 against fifth stage *Hypoderma lineatum*. It is believed that at least part of this lower than expected mortality is due to the fact that all expressed grubs were warmed and examined under the microscope. It was noted that invariably a sizeable number of those declared dead when examined in the field proved to be alive when examined in the laboratory. Another factor of importance is the extremely low natural mortality rate. This is shown by item 8 of table 1 for *Hypoderma lineatum* and by items 5 and 7 for *H. bovis*. Other investigators have reported natural mortality rates of 25 per cent or more. Such high natural mortalities are due at least in part to reliance upon field determination of death.

There is a definite line of demarcation separating the insecticides into effective and ineffective groups. The effective group includes the first three formulae of table 1, which are all preparations containing 5 per cent rotenone powder as the principal active ingredient. The ineffective group includes insecticides 4, 5, 6, and 7, benzene hexachloride, liquid rotenone extract, and two chlordan preparations respectively.

In the past variable results have been reported in controlling cattle grubs with benzene hexachloride. The very poor results obtained with the material here are in accord with the report of Annand (1947), who stated that benzene hexachloride proved ineffective at concentrations as high as 1 per cent gamma isomer when tested against the common cattle grub. Telford (1947) also has indicated that benzene hexachloride dusts were ineffective at 1 to 3.7 per cent gamma isomer content, although he obtained fair to good

Table 1.—Results of insecticide tests against cattle grubs.

FORMULA		ANIMALS TREATED	FIFTH STAGE GRUBS				FOURTH STAGE GRUBS			
			H. bovis		H. *lineatum*		H. *bovis*		H. *lineatum*	
			Grubs treated	Per cent killed	Grubs treated	Per cent killed	Grubs treated	Per cent killed	Grubs treated	Per cent killed
1. 5 per cent rotenone Wettable sulphur Detergent Water	10 lbs. 10 lbs. 1 pint 100 gals.	126	88	38	204	64	3	100	38	55
2. 5 per cent rotenone Water	10 lbs. 100 gals.	12	12	33	67	64	0	—	3	33
3. 5 per cent rotenone Water	7.5 lbs. 100 gals.	92	47	38	131	60	5	100	39	38
4. 50 per cent wettable benzene hexachloride mixture containing 5 per cent gamma isomer Water	8 lbs. 100 gals.	20	0	—	39	8	0	—	15	13
5. Liquid rotenone extract (containing 2.5 per cent rotenone) Water	2.5 qts. 100 gals.	12	34	3	87	7	2	0	8	38
6. Chlordan (50 per cent wettable dust) Water	4 lbs. 100 gals.	6	0	—	33	6	0	—	43	0
7. Chlordan (45 per cent emulsifiable concentrate) Water	1 gal. 100 gals.	27	39	0	128	5	1	0	14	7
8. No treatment		10	0	—	36	3	0	—	13	0

Table 2.—Data for comparative analysis of the most effective formulae.

		$j=$	1	2	3	
			5th Stage Grubs		4th Stage Grubs	
i	INSECTICIDAL FORMULA	*	*Hypoderma bovis*	*H. lineatum*	*H. lineatum*	TOTAL OF 3 GROUPS
1.	Rotenone 5 per cent	10 lbs.	$n_{1}j$ 88	204	38	$N_1=330$
	Wettable sulphur	10 lbs.	$q_{1}j$ 0.38	0.64	0.55	$q_{1.}=$ 0.5600
	Detergent	1 pint	$q_{1}j^2$ 0.1444	0.4096	0.3025	$q_{1.}^2=$ 0.3136
	Water	100 gal.				
2.	Rotenone 5 per cent	10 lbs.	$n^{2}j$ 12	67	3	$N^2=$ 82
	Water	100 gal.	$q_{2}j$ 0.33	0.64	0.33	$q_{2.}=$ 0.5833
			$q_{2}j^2$ 0.1089	0.4096	0.1089	$q_{2.}^2=$ 0.3402
3.	Rotenone 5 per cent	7.5 lbs.	$n_{3}j$ 47	131	39	$N_3=217$
	Water	100 gal.	$q_{3}j$ 0.38	0.60	0.38	$q_{3.}=$ 0.5128
			$q_{3}j^2$ 0.1444	0.3600	0.1444	$q_{3.}^2=$ 0.2630
						$N=629$
						$q_{..}=$ 0.5468
						$q_{..}^2=$ 0.2990

*i = insecticide number
n = number in sample
q = proportion of sample killed
N_1 = sum of n values = 88 + 204 + 38.
$q_{1.}$ to $q_{3.}$ = means of proportions killed by each insecticide.

$$q_{1.}=\frac{\sum^{3} q_{1}j\, n_{1}j}{N_1}$$

$q_{..}$ = arithmetic mean of the 3 means.

results with benzene hexachloride ointments at gamma isomer concentrations of 0.3 to 0.9 per cent.

The very poor control obtained with liquid rotenone extract was quite unexpected in view of the claims which have been made for this material when used at the recommended concentration. However, it should be noted that in order to have an amount of rotenone in this preparation equivalent to that in formula 3, approximately 7.5 quarts of the liquid extract per 100 gallons of water would be required.

Although Telford (1947) in preliminary tests with chlordan found that an ointment containing 5 per cent chlordan, 90 per cent linseed oil, and 5 per cent water was effective when applied with a spatula, the results from use of the two spray preparations of chlordan reported here indicate that the material is ineffective when applied as a spray.

Since the insecticides 4 to 7 were obviously ineffective, further comparative tests with them were not conducted. Analysis of the three most effective materials was made using data on the control of fifth stage *Hypoderma bovis*, fifth stage *H. lineatum*, and fourth stage *H. lineatum*. Fourth stage *H. bovis* were excluded from consideration in this analysis since so few were recovered. The data used in this computation are given in table 2.

A test was first set up for the hypothesis that both the stages and the species represented in table 2 were equally susceptible to any of the three listed insecticides.

The chi square value[1] for this 9-cell comparison is 33.675, with 8 degrees of freedom. The probability of such a value of chi square occurring by chance is far less than 1 per cent; therefore, the hypothesis is rejected.

Accepting that a significant difference is involved in the percentage kills represented in table 2, it was desirable to know if the fifth stage grubs of each species and the fourth stage of *Hypoderma lineatum* all are of equal susceptibility to the action of insecticides. This involves several hypotheses, the first of which is that fifth stage *H. bovis*, fifth stage *H. lineatum*, and fourth stage *H. lineatum* are equally susceptible to the rotenone sulphur mixture (Formula 1). The value of chi square[2] for

[1] $$\chi^2=\sum_{i=1}^{3}\sum_{j=1}^{3} n^{ij}\frac{(qij-q..)^2}{q..\,(1-q..)}.$$

[2] $$\chi^2=\sum_{j=1}^{3} n^{ij}\frac{(q_{ij}-q_{i.})^2}{q_{i.}\,(1-q_{i.})}.$$

this hypothesis is 17.34 with 2 degrees of freedom. The possibility of such a value of chi square occurring by chance is far less than 1 in 100; therefore, the hypothesis is rejected.

The second hypothesis of this series is that the above-mentioned stages and species of grubs are equally susceptible to 5 per cent rotenone at the rate of 10 pounds to 100 gallons of water (insecticidal formula 2). Using the same formula as above, a chi square value of 4.86 is obtained with 2 degrees of freedom. This value could occur by chance about 9 times in 100; therefore, on the basis of these limited data we may only provisionally reject the second hypothesis.

The third hypothesis of this series is that fifth stage *Hypoderma bovis*, and fifth and fourth stages of *H. lineatum* are equally susceptible to 5 per cent rotenone at the rate of 7.5 pounds to 100 gallons of water (insecticidal formula 3). Using the same formula for chi square, a value of 10.04 is obtained with 2 degrees of freedom. The possibility of such a value occurring by chance is 1 in 100; therefore, the third hypothesis is rejected.

Summarizing the data on chi square values for the above three hypotheses, a chi square of 32.124 is obtained with 6 degrees of freedom. The possibility of this value occurring by chance is far less than 1 in 100; therefore, we can reject the overall hypothesis that fifth stage *Hypoderma bovis*, and fifth and fourth stage *H. lineatum* as a group are equally susceptible to each of the three most effective insecticidal formulae tested.

It is also desirable to know if fifth stage *Hypoderma bovis* larvae are significantly more or less resistant to a given insecticide than are fifth stage *H. lineatum*. This entails a breakdown of the data into such small components that it is possible to make such comparisons only with insecticide formulae 1 and 3. This analysis[1] of the difference in kill of fifth stage *H. bovis* and fifth stage *H. lineatum* with either the rotenone-sulphur mixture (formula 1) or with 7.5 pounds of 5 per cent rotenone per 100 gallons of water (formula 3) allows us to conclude that fifth stage *H. bovis* are significantly more resistant to these two insecticides than are fifth stage *H. lineatum*.

It is apparent from this analysis that in any critical test of an insecticide for cattle grubs the stage (fourth or fifth) and the species of grub must be recorded and considered. This is especially important when any two insecticides under comparison are in the same general range of toxicity. Where information relative to screening materials into comparatively effective and ineffective groups is the main objective, the stress placed on differential kills between species and stages of grubs may be minimized.

In order to compare the relative value of the three most effective formulae tested against cattle grubs, the data in table 2 were analyzed to test the hypothesis that the insecticidal means (q1., q2., q3.) are the same. A chi square value[2] of 1.551 was obtained with 2 degrees of freedom. The probability of such a value occurring by chance is about 50 per cent; therefore, within the limits of the data reported here we must tentatively conclude that the over-all insecticidal activities of the three most effective formulae are the same.

As pointed out by Stewart (1944), it is very important to obtain the best possible kill of fourth stage grubs, since the earlier the grubs are killed the less damage they can do. Also under a normal schedule of successive treatments at 30-day intervals, many fourth stage grubs which survive a treatment will have matured and left the animal before it is retreated. Unfortunately our data on fourth stage grubs of *Hypoderma bovis* are too scanty to allow analysis. However, using the data on kill of fourth stage *H. lineatum* some interesting leads are indicated. Here the data are only sufficiently complete to show certain probable trends. As seen in table 2, formula 1, the rotenone sulphur mixture gave a 55 per cent kill of fourth stage grubs while formula 3, consisting of 5 per cent rotenone at 7.5 pounds to 100 gallons of water, gave only a 38 per cent kill. However, due to the relatively small sample sizes (38 and 39 respectively) it

[1] $$q_0 = \frac{q_1 n_1 + q_2 n_2}{n_1 + n_2}.$$

$$\text{Standard error} = \sqrt{q_0 1 - q_0 \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}.$$

q_0 = modified average per cent kill of grub samples.
q_1 and q_2 = per cent of grub samples killed.
n_1 and n_2 = sample size.

[2] $$X^2 = \sum_{i=1}^{3} Ni \frac{(qi. - q..)^2}{q.. (1 - q..)}$$

was determined that such variation could occur by chance about 15 times in a hundred. Therefore, although the data support the view that rotenone sulphur is more effective against fourth stage *H. lineatum* additional data will be required to prove the point.

A further indication that formula 1 (rotenone-sulphur) was somewhat superior to formula 3 (5 per cent rotenone at 7.5 pounds to 100 gallons water) in killing fourth stage *Hypoderma lineatum* larvae is found in the following statements of hypotheses which were found to be statistically probable.

1. The insecticidal activity of formula 1 against fourth stage *Hypoderma lineatum* is the same as that of insecticide 3 against fifth stage *H. lineatum*.

2. The insecticidal activity of formula 3 is greater against fifth stage than fourth stage *Hypoderma lineatum*.

SUMMARY AND CONCLUSIONS.—Several insecticides were tested for comparative kill of cattle grubs when applied as a spray at 350 to 400 pounds pressure. The data obtained divide the tested materials into effective and ineffective groups. The effective materials were:

1. Standard rotenone-sulphur spray (10 pounds 5 per cent rotenone, 10 pounds wettable sulphur, 1 pint detergent, 100 gallons water).
2. 10 pounds of 5 per cent rotenone to 100 gallons water.
3. 7.5 pounds of 5 per cent rotenone to 100 gallons water.

The following materials were ineffective:

4. Eight pounds of benzene hexachloride 50 per cent wettable powder containing 5 per cent gamma isomer in the mix, and water 100 gallons.
5. 2.5 quarts of 2.5 per cent rotenone as a liquid rotenone extract to 100 gallons water.
6. Four pounds of 50 per cent wettable chlordan dust to 100 gallons of water.
7. One gallon of 45 per cent emulsifiable concentrate of chlordan to 100 gallons of water.

Statistical analysis of the data on insecticidal activity of the three effective combinations tested demonstrated that in any critical test of an insecticide for cattle grubs the stage (fourth or fifth) and the species of grub must be recorded and considered. These tests indicated furthermore that fifth stage *Hypoderma bovis* are significantly more resistant than fifth stage *H. lineatum* to insecticide formulae numbers 1 and 3 as designated above.

Considered on the basis of over-all kill of all grubs the insecticidal activity of the rotenone sulphur mixture (insecticide formula 1) was not significantly different from that of 5 per cent rotenone at either 7.5 pounds or 10 pounds to 100 gallons of water. However, on the basis of comparative kills of fourth stage *Hypoderma lineatum* there are indications pointing to the superiority of the rotenone sulphur mixture over 5 per cent rotenone at 7.5 pounds to 100 gallons of water.—6-18-48.

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R. T. Everly, formerly with the Division of Cereal and Forage Crop Insects of the Bureau of Entomology and Plant Quarantine, has recently gone with the Department of Entomology of the Purdue University Agricultural Experiment Station. His major problems will deal with legume insects.

Tests of the Permeability of Fabrics to Biting by Mosquitoes[1]

J. P. LINDUSKA[2] and FRED A. MORTON, *U.S.D.A. Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[3]

As part of its general research program on insects of importance to the armed forces, the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine conducted a search for methods of protecting individuals against biting insects. Chemical repellents suitable for skin application were tested, and the permeability of cloths of different weaves to biting by mosquitoes was determined. Later an investigation was begun on possible methods of impregnating clothing with chemicals to render it repellent to mosquitoes.

Liquid repellents were developed (Travis *et al.* 1946) that were effective as a skin application for several hours under favorable conditions, and when applied to clothing these materials were found to repel most species of mosquitoes for as long as a week (Travis and Morton 1947). However, even in areas of high malaria incidence, mosquitoes frequently were not abundant enough to encourage individuals in the consistent application of repellents, and the field treatment of clothing to give adequate protection presented various difficulties. The herringbone-twill fatigue uniforms in general use during the war offered little impediment to biting by mosquitoes. A definite need existed for a personal prophylactic which would not be dependent upon individual initiative for effect, and would be capable of providing protection for extended periods.

From late in 1943 until early in 1945 a large number of sample fabrics and articles of clothing were received from the Quartermaster Corps of the United States Army and others, and tested in the laboratory for their ability to protect against biting by mosquitoes. A number of the fabrics were subsequently tested in the field as sample suits. The results of these studies, some of which were conducted cooperatively by Army units and the Orlando laboratory, are summarized in this paper.

LABORATORY SCREENING TESTS. *Methods.*—A small cage, 12 by 10 by 10 inches, with a glass top and screens on two sides was used in these tests. The bottom of the cage was convex, the curve being of dimensions (7 inches wide by 5 inches deep) to fit the fore part of the thigh above the knee. An opening 2 inches wide and running the length of the cage bottom was fitted with a draw plate. A seated subject placed a piece of sample fabric over the front of the thigh above the knee, set the cage over the cloth, and withdrew the slide to give the mosquitoes access to the fabric. By adjusting the size of the aperture it was possible to control the number of mosquitoes on the cloth patch. A flashlight was used to illuminate the test area so that all activity could be closely observed. Since *Anopheles quadrimaculatus* Say is inclined not to bite in strong light, practically all laboratory tests were made with *Aëdes aegypti* (L.).

The exposure time was variable, and consideration was given only to the number of mosquitoes landing on the cloth and the number that were successful in biting through it. From these figures the percentage of permeability was computed. These percentages are of value only in a comparative sense and do not show the absolute protection or lack of protection provided by a given fabric. This interpretation of the data is necessary, since it cannot be presumed that all mosquito landings represent attempts to bite. The method used was sufficiently accurate to permit a relative grading of fabrics and to eliminate from further consideration an appreciable number of samples. Final selection of materials for mosquito-resistant clothes should, of course, be made on the basis of actual field tests, following laboratory analyses by more refined and exacting techniques.

Results.—The results of these tests on 56 samples are given in table 1. Nine cloth

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

[2] Now with Fish and Wildlife Service, U. S. Department of the Interior.

[3] The writers acknowledge the assistance given in laboratory tests by B. V. Travis, James H. Cochran, and Fred M. Snyder. Grateful acknowledgment is extended to Lt. Col. Norman W. Elton, M. C., U. S. Army, and Bradford B. Owen, Engineering Division, Air Technical Service Command, Wright Field, Dayton, Ohio, for granting permission to include selected data from some field tests arranged for and largely directed by them.

Table 1.—Permeability of sample fabrics to biting by *Aëdes aegypti*—Laboratory tests.

SAMPLE NO.	TYPE OF FABRIC	TOTAL LANDINGS	TOTAL BITES	PER CENT PERMEABILITY
	Fabrics with a permeability of 5 per cent or less			
1	Jo-cloth type fabric (165×68). 80/3 warp, 60/4 filling	159	0	0
2	Nylon-filled, poplin warp	115	0	0
3	Byrd cloth (standard)	370	0	0
4	Wind-resistant oxford (167×59), 3.00, 26.5/1×21/1	113	0	0
5	Poplin (standard, green)	385	1	<1
6	Blanket nylon fabric	369	1	<1
7	Blanket nylon fabric (calendered)	353	1	<1
8	Plain weave. Cotton warp, nylon filling	150	1	<1
9	Cotton uniform twill, 8.2 oz.	424	3	<1
10	Blanket nylon fabric	376	5	1
11	Blanket nylon fabric	373	7	2
12	Blanket nylon fabric	356	7	2
13	Blanket nylon fabric	401	10	2
14	Plain weave. Cotton warp, nylon filling	162	4	2
15	Blanket nylon fabric	302	9	3
16	Twill weave. Cotton warp, nylon filling	182	5	3
17	Poplin warp, crowfoot weave	323	14	4
18	Rayon-carbon black, 104 threads per inch (washed)	248	10	4
19	Rayon-carbon black, 104 threads per inch (unwashed)	85	4	5
20	Rayon-carbon black, 116 threads per inch (washed)	120	0	0
21	Rayon-carbon black, 116 threads per inch (unwashed)	285	3	1
	Fabrics with a permeability of more than 5 per cent			
22	Imitation Byrd cloth, 2.65, 172×100 warp 40/1 Peeler, filling 40/1 Peeler, single yarn	148	9	6
23	Poplin warp, crowfoot weave	193	12	6
24	Imitation Byrd cloth, 2.95, 184×100 warp 52/1 Pima, filling 38/1 Pima, single yarn	148	11	7
25	Imitation Byrd cloth, 2.75, 164/100, warp 40/1 Peeler, filling 40/1 Peeler, single yarn	154	11	7
26	Twill weave, cotton warp, nylon filling	115	8	7
27	Poplin warp, crowfoot weave	220	16	8
28	Poplin warp, crowfoot weave	196	18	9
29	Carbon-rayon twill	102	10	10
30	Shirting, oxford weave, 6 oz. (109×57) warp 21/1, filling 23/1	184	19	10
31	Poplin warp, crowfoot weave	290	33	11
32	Imitation Byrd cloth. Twill, 2×2, sanforized and dyed (116×68) 60/2 warp and filling mercerized	110	12	11
33	Blanket nylon fabric (uncalendered)	276	33	12
34	Poplin warp, crowfoot weave	189	25	13
35	Poplin warp, crowfoot weave	181	24	13
36	Poplin warp, crowfoot weave	189	25	13
37	Poplin, tan (standard) 128×68, 4 oz.	119	16	13
38	Broadcloth (standard) 136×60, 3.2 oz.	79	11	14
39	Herringbone twill (standard)	140	20	14
40	Poplin warp, crowfoot weave	173	26	15
41	Nylon, 3.70 oz. per sq. yd., twill weave, warp 105/34, filling 210/69	108	23	21
42	Variation of 6-oz. army shirting, 2×1 twill	99	22	22
43	Nylon cloth	65	16	24
44	Nylon cloth	50	12	24
45	Nylon cloth	98	26	26
46	Wool shirt, British Army	98	28	28
47	Nylon cloth	94	33	35
48	Nylon cloth	61	23	38
49	British cellular, tropical weave	123	60	49
50	Cotton seersucker, gray (Red Cross)	42	23	55
51	Nylon cloth	68	42	62
52	Nylon, 1.80 oz. per sq. yd., twill weave, warp 70/23, filling 70/23	71	46	65
53	Nylon cloth	50	38	76
54	Nylon cloth	70	59	84
55	Nylon cloth	64	56	88
56	Camouflage suit. Fortisan cloth, yarn mesh fabric	10	9	90

Table 2.—Tests of washed and unwashed samples of fabrics for permeability to mosquito biting.

Sample No.	Type of Fabric	Unwashed			Washed		
		Total Landings	Total Bites	Per Cent Permeability	Total Landings	Total Bites	Per Cent Permeability
1	Blanket nylon fabric, calendered	162	1	0	202	0	0
2	Blanket nylon fabric, uncalendered	126	13	10	107	11	10
3	Blanket nylon fabric, uncalendered	176	5	3	157	4	3
4	Blanket nylon fabric, uncalendered	173	9	5	135	0	0
5	Blanket nylon fabric, uncalendered	130	6	5	163	2	1
6	Blanket nylon fabric, uncalendered	130	5	4	161	2	1
7	Blanket nylon fabric, uncalendered	133	1	1	154	1	1
8	Blanket nylon fabric, uncalendered	108	4	4	150	5	3
9	Herringbone twill, standard, impregnated with CC-2 impregnite	103	0	0	108	0	0
10	Herringbone twill, standard, impregnated with CC-2 impregnite	138	2	1	101	1	1
11	Herringbone twill, standard, impregnated with CC-2 impregnite	138	1	1	105	3	3
12	Poplin warp, crowfoot weave	137	5	4	111	4	4
13	Poplin warp, crowfoot weave	108	5	5	108	7	7
14	Poplin warp, crowfoot weave	95	4	4	116	6	5
15	Poplin warp, crowfoot weave	194	20	11	172	11	7
16	Poplin warp, crowfoot weave	92	12	13	85	12	14
17	Poplin warp, crowfoot weave	88	12	13	55	20	36
18	Poplin warp, crowfoot weave	93	15	16	85	13	15
19	Poplin warp, crowfoot weave	130	15	12	117	9	8
20	Poplin warp, crowfoot weave	107	12	11	107	11	10
21	Byrd cloth (standard)	121	0	0	150	0	0
22	Cotton uniform twill, 8.2 oz.	125	0	0	129	0	0
23	British cellular tropical weave	44	30	68	50	32	64
24	Poplin (standard, green)	139	1	1	107	0	0
25	Herringbone twill (standard)	140	20	14	148	12	9
26	Poplin, tan (standard) 128×68, 4 oz.	119	16	13	132	23	17
27	Oxford (167×59), 3.00, 26.5/1×21/1	113	0	0	101	1	1
28	Jo-cloth type fabric (165×68), 80/3 warp, 60/4 filling	159	0	0	102	0	0
29	Nylon-filled, poplin warp	115	0	0	140	0	0
30	Broadcloth (standard), 136×80, 3.2 oz.	79	11	14	123	12	10
31	Carbon-rayon twill	109	16	15	102	10	10

Table 3.—Tests of gloves for resistance to biting by laboratory-reared *Aëdes agypti* and *Anopheles quadrimaculatus* mosquitoes.

Sample No.	Style and Fabric Type	*Aëdes aegypti*			*Anopheles quadrimaculatus*		
		Landings	Bites	Permeability	Landings	Bites	Permeability
1	Standard mosquito gloves of 10 oz. Canton flannel	400+	3	1%	100+	2	2%
2	Mosquito gloves, knit wristlet, 7.9 duck	400+	16	4	100+	4	4
3	Mosquito gloves, gauntlet, 7.9 duck	400+	12	3	100+	7	7
4	Mosquito gloves of 10 oz. Canton flannel, without fingers and with palm cut out	400+	1	1%	100+	2	2%
5	Flannel-lined duck, gauntlet type	250	1	1	200	1	1
6	Flannel-lined duck, gauntlet type	43[1]	3	7	84[1]	5	6
7	Air Corps mechanic's glove, leather[2]	500+	0	0	300+	0	0
8	Dress glove, cape leather[2]	500+	0	0	300+	0	0
9	Byrd cloth, leather reinforced[2] experimental antimosquito glove	500+	0	0	300+	0	0

[1] Counts made only on knuckles at points of extreme stress.
[2] Tested for over-all protection when worn with K-1 summer flying suit. Shortness of cuff and poor closure of mechanics glove allowed some biting on wrist.

samples were practically impervious to biting by mosquitoes, having allowed fewer than 1 per cent of the mosquitoes to penetrate. However, all the cloths showing permeability of 5 per cent or less are considered to give good protection. By comparison, herringbone twill (No. 39), the present standard for fatigue dress, was found to be 14 per cent permeable.

The thermal properties of many of these fabrics are not well known. The rayon-carbon black (Nos. 18 to 21) is of heavy weight and obviously would not be suitable for wear in warm temperatures. However, most of the fabrics in the group giving good protection are of a lighter weight and thinner than herringbone twill, and appeared to be much more suitable for semitropical or warm-weather use.

Effect of Calendering of Cloth.—Sufficient samples of calendered fabrics were not available for determining the extent to which such treatment might lessen the permeability of fabrics to mosquito biting. A single type of rather heavy nylon, tested plain and calendered, indicated favorable results. The plain sample of this cloth (No. 35, table 1) permitted frequent penetrations (12 per cent permeability), whereas the calendered sample (No. 7) allowed only 1 bite in 353 landings. Field tests of light-weight nylon suits showed no appreciable differences between calendered and uncalendered fabrics. However, because these fabrics were of extremely light weight and open mesh, it is possible that calendering had not altered the porosity of the cloth to a degree which would provide a measurable difference in resistance to biting.

Effect of Washing on Permeability of Cloth.—To determine the effect of washing on the permeability of different fabrics a portion of each sample was washed three times and then tested dry concurrently with unwashed portions of the sample. The results of these tests on 31 samples are summarized in table 2. With a single exception (No. 17) washing had no pronounced effect on permeability. This sample, with a permeability that increased from 13 to 36 per cent, was 1 of 9 samples of similar weave and weight, and since corresponding trends were not noted in any of the other eight samples, it is not likely that the apparent difference in this case was significant. Averages for all the samples seem to point to a slight increase in resistance to biting following washing, a factor that could be accounted for by cloth shrinkage. This trend seems to be particularly true with a number of nylon samples (Nos. 1 through 8), although the differences are hardly significant.

Tests of Gloves.—Several styles and types of gloves submitted by the Quartermaster Corps were tested by inserting a gloved hand in cages of *Aëdes aegypti* and *Anopheles quadrimaculatus* mosquitoes. An approximate count of landings on the clenched hand and back of the wrist, where the cloth was in close contact, was obtained, and an actual count of the mosquitoes biting through the same area was also made. The results of these tests are presented in table 3. Although practically all of these materials were reasonably effective in preventing biting, the weight and style of most models would seem to make them unsatisfactory for use in warm weather. When qualities other than permeability were considered, such as coolness and wearing qualities, the experimental Byrd-cloth model (No. 9), was far superior to the other gloves tested.

Tests of Netting Worn in Combination with Other Fabrics.—Nettings of different thickness and mesh were tested to determine whether a light, open-weave fabric lined with a suitable netting might be developed as a mosquito-proof combination. The results of a few of these studies are given in table 4. An arm cage similar to the previously described leg cage was modified to permit placement of the arm over a slide-controlled aperture near the top of the cage. A canvas sleeve, also used in the tests, had a metal frame with an opening 1.5 by 3.5 inches on one side. Cloth patches, alone or with pieces of netting, were clamped over the opening from the inside. A zipper opening on the opposite side of the sleeve facilitated insertion and removal of the test cloths. Rubber bands were placed around the arm and over each end of the projecting frame to hold the cloth in tight contact with the arm surface. In other tests a section of netting was placed over the forearm, held in place by rubber bands, and the sleeve of a garment was worn over it. Tests were made against both *Aëdes aegypti* and *Anopheles quadrimaculatus* by inserting the arm alternately in cages containing three to four thousand mosquitoes.

Three types of netting were used—(1)

Table 4.—Tests of fabrics lined with nettings for permeability to mosquito biting.

Materials Tested	*Aëdes aegypti*			*Anopheles quadrimaculatus*		
	Landings	Bites	Per Cent Permeability	Landings	Bites	Per Cent Permeability
Camouflage suit sleeve:						
Alone	10	9	90	10	8	80
Over Brynje-vest netting	50	0	0	50	0	0
Over imitation Brynje-vest netting	50	0	0	50	1	2
Over thin netting	128	3	2.3	285	103	36.1
Herringbone-twill suit sleeve over thin netting	139	2	1.4	285	5	1.7

a Brynje-vest netting of sixteenth to eighth inch diameter cord loosely knotted to provide 0.5 to 0.75-inch openings (the overlapping cord gives an average thickness of less than 0.25 inch), (2) a manufactured imitation of the Brynje-vest netting of raschel knit with openings 0.25 to 0.5 inch and with a thickness of about 0.1 inch, and (3) a light-weight netting, approximately 0.05 inch in thickness, with meshes of about 0.25 inch.

The two heavier nettings provided excellent protection against both *Aëdes aegypti* and *Anopheles quadrimaculatus* when worn under samples of a highly porous garment such as the Fortisan cloth camouflage suit. The thinner netting proved effective against both species when worn with herringbone-twill cloth, but in combination with the camouflage suit material it was ineffective against *Anopheles quadrimaculatus* and also allowed more penetrations by *Aëdes aegypti.*

FIELD TESTS OF SAMPLE SUITS.—To determine the penetrability of fabrics under conditions of field wear, a few preliminary tests were conducted in the vicinity of Key West, Fla., during the fall of 1943. Sample fatigue suits of Byrd cloth, poplin, 8.2-ounce cotton twill, herringbone twill, and British cellular weave were found to be effective against salt-marsh mosquitoes, *Aëdes taeniorhynchus* (Wied.), in the order given. Byrd cloth provided excellent protection, and poplin and twill allowed less than 5 per cent of the mosquitoes landing on the shoulder area to penetrate. Herringbone twill and British cellular weave allowed frequent biting and were conspicuously less effective than the others. These tests were made when the mosquito population was diminishing, and it was not until the summer of 1944 that additional information based on comprehensive field work was obtained.

Methods.—Tests were begun July 25, 1944, at Camp Indian Bay, Brooksville, Fla., but a marked decline in the mosquito population necessitated a discontinuance of the studies on August 4. Work was continued, and in a large measure reconducted, against *Aëdes taeniorhynchus* at Merritt Island, near Cocoa, Fla., from August 15 to 18. Of the 40 men used as subjects at Camp Indian Bay, 16 who reacted postively to mosquito biting by the evidence of conspicuous wheals were transferred to Cocoa, where the work was done with the group on bivouac in the area.

At Cocoa each test subject was provided with a complete series of suits to be tested. Possible known sources of considerable error, such as interpreting the value of a given fabric on the basis of its performance when worn by a single individual or the wearing of a single garment by individuals differing in body size, were by this means largely eliminated. Prior to exposure the men were examined, and existing wheals or eruptions that might later be confused were marked with gentian violet. The subjects were then taken to a test area, where they were seated circular fashion so that each man could observe the mosquito activity on the back (area between collar and belt and between side seams) of the man in front of him. The biting rate of mosquitoes was usually such that 50 to 100 bites were received on the exposed lower leg (knee to ankle) in a 30-second exposure. Exposures were for 30-minute periods, and the landing and biting counts were recorded at the end of 10-minute intervals. After each exposure the subjects were moved to an outdoor area

Table 5.—Field tests of permeability of fatigue suits to mosquito biting.[1]

SAMPLE NO.	UNIFORM FABRIC	TOTAL LANDINGS ON BACK	TOTAL BITES ON BACK THROUGH FABRIC	PER CENT PERMEABILITY	BITES PER 1000 LANDINGS
1	Nylon-filled poplin	26,053	40	0.15	2
2	Byrd cloth	24,935	58	.23	2
3	Nylon	24,061	116	.48	5
4	Jo cloth	14,061	80	.57	6
5	Poplin WRT	4,502	263	5.8	58
6	Poplin 5 oz.	4,180	336	8.0	80
7	8.2-oz. twill	4,549	356	7.8	78
8	Herringbone twill[2]	683	143	21.0	210

[1] This table is a partial summary of information from a report by Lt. Col. Norman W. Elton to the Quartermaster Board, Camp Lee, Va., on Aug. 23, 1944.
[2] Biting through this fabric was so severe that men wearing these uniforms were removed from the test, and the suits were omitted from further tests.

made reasonably free of mosquitoes by liberal treatment with pyrethrum aerosol and a count of wheals was made. The count of wheals was found to be a more reliable figure of actual penetrations than the observed bite count and was the one principally used as a basis for calculation.

Results.—The results of these studies are given in table 5.

The same procedure was used later in tests of flying suits. Since only a single suit of each fabric type was available, each suit was tested on eight test subjects. The results of these tests are summarized in table 6.

Although none of the fabrics provided complete protection against biting by mosquitoes, a number of them allowed so few penetrations that for all practical purposes they could be considered mosquito-proof. Several were worn with complete comfort under the extreme conditions provided by the Merritt Island area (table 5, Nos. 1 through 4; and table 6, Nos. 1 through 5). Byrd cloth consistently proved to be a highly effective material. Suits of tightly woven, heavy-weight (3 oz.) nylon permitted a low percentage of penetrations under field conditions (No. 3, tables 6 and 7) but lighter weight nylon fabrics (1.75 oz.) were entirely ineffective (Nos. 11 to 13, table 6). Tightly woven cotton twill (No. 2, table 6) gave good protection against salt-marsh mosquitoes in field tests and confirmed laboratory results for a similar material. Suits of nylon-

Table 6.—Field tests of permeability of flying suits to mosquito biting.[1]

SAMPLE NO.	UNIFORM FABRIC	TOTAL LANDINGS ON BACK	TOTAL BITES ON BACK THROUGH FABRIC	PER CENT PERMEABILITY	BITES PER 1000 LANDINGS
1	Byrd cloth (cotton)	1758	9	0.51	5
2	Cotton twill, 132×84	1586	13	.82	8
3	Nylon, 302	1865	26	1.4	14
4	Byrd cloth, substitute	1917	30	1.5	15
5	Gabardine (cotton and wool)	1596	26	1.6	16
6	Poplin (cotton)	2504	91	3.6	36
7	Khaki twill, 6 oz.	117	7	6.0	60
8	Herringbone twill, Class B	122	28	23.0	230
9	Herringbone twill, Class A	183	56	31.0	310
10	Herringbone twill, Class X	167	81	48.0	480
11	Nylon, light navy, 1.75 oz. calendered	74	48	65.0	650
12	Nylon, light navy, 1.75 oz. uncalendered	203	137	67.0	670
13	Nylon, light navy, 1.75 oz.	68	47	69.0	690
14	Light nylon (worn over net vest)[2]	1503	2	0.13	1
15	Nylon, calendered, over netting[3]	2120	18	0.85	9

[1] Compiled from information included in a memorandum report Oct. 12, 1944, by Bradford B. Owen, Wright Field, Dayton, Ohio
[2] Manufactured imitation Brynje vest. Raschel knit, cotton, half-inch mesh, thickness 0.1 inch.
[3] Raschel knit, cotton, quarter-inch mesh, square opening, thickness 0.07 inch.

filled poplin and Jo cloth (Nos. 1 and 4, table 5) were found to be practically impervious to biting. Both these fabrics are somewhat heavier and thicker than Byrd cloth and appear to be more resistant to tearing and snagging. A single cotton and wool gabardine flying suit (No. 5, table 6) allowed only occasional penetrations. It is suspected, however, that the protective features of this particular suit were associated with the thickness of the fabric, which was more than twice that of the poplin, twill, and Byrd cloth.

The fabrics which provided only moderate or slight protection included poplin (5 oz.), twills (8.2 oz., 6 oz., and herringbone), and several types of light nylon (tables 5 and 6). Herringbone twill showed permeabilities of 21, 23, 31, and 48 per cent for the four classes tested, and three types of very light-weight and porous nylon suits allowed penetrations of 65, 67, and 69 per cent.

Net Vests Worn with Permeable Fabrics.—Preliminary field studies (not reported here) showed that mosquito biting through permeable fabrics was practically eliminated when a net-type undergarment, such as a Brynje vest, was worn beneath permeable outer clothes. In these studies two additional types of netting were tested in combination with the most permeable fabrics tested. The results are shown in table 6 (Nos. 14 and 15). When worn alone, two light nylon suits (Nos. 11 and 13) offered practically no impediment to biting by mosquitoes. The same suits worn over two types of netting showed a permeability of less than 1 per cent. The imitation Brynje vest worn beneath a light nylon suit (No. 14) permitted only 0.13 per cent penetration and was more effective from a mosquito-protection standpoint than were any of the resistant fabrics worn alone. Byrd cloth (No. 1), the most effective material in this series of tests, was found to be 0.51 per cent permeable. The second type of netting (No. 15), worn with a highly permeable light nylon fabric, gave protection about equal to that of the best fabrics worn alone.

The above observations suggest the possibility of lining a lightweight porous fabric with a coarsely woven, open-mesh netting as an approach to the development of a mosquito-proof combination. The thermal effects associated with net liners of the type tested in the field may be such as to limit their use to restricted situations. However, preliminary laboratory tests have shown that the thickness of netting can be considerably less than that of the field-tested liners without an appreciable loss of effectiveness.

SUMMARY.—Of 56 fabrics tested in the laboratory to determine their permeability against biting by mosquitoes, 9 were practically impervious to biting by *Aëdes aegypti* (L.), having allowed fewer than 1 per cent of the mosquitoes to penetrate, and most of the others appeared acceptable from other standpoints for use as protective clothing. Field tests of a number of these fabrics substantiated results found in the laboratory. Suits of Byrd cloth, nylon-filled poplin, Jo cloth, heavy nylon, and one style of cotton twill were found to provide a high measure of protection against biting by mosquitoes. Herringbone twill, a fabric commonly used in fatigue uniforms, was only slightly resistant.

A single sample of a calendered nylon fabric showed an appreciably greater resistance to penetration by mosquitoes than the same cloth uncalendered. The possibility of reducing porosity of fabrics by mechanical means is suggested.

Samples of 31 fabrics that had been washed three times and then tested dry concurrently with unwashed portions of the same samples gave no significant indication that washing had altered the permeability of the fabrics.

Biting through highly permeable fabrics was eliminated or markedly reduced when such fabrics were removed from direct contact with the body surface by means of coarsely woven, open-mesh netting materials. Laboratory tests of several types of netting worn beneath open-weave fabrics showed favorable results, and indicated that such a combination might prove to be expedient under some conditions.

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Comparative Toxicity of Four Chlorinated Organic Compounds to Mosquitoes, House Flies, and Cockroaches[1]

J. B. Gahan, I. H. Gilbert, R. L. Peffly, and H. G. Wilson,[2] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Recently benzene hexachloride, chlordan, and chlorinated camphene have been widely tested, usually in comparison with DDT, to determine their effectiveness against various species of insects. British investigators were working with benzene hexachloride as early as 1942, and Slade (1945) referred to its toxicity to house flies, mosquitoes, and cockroaches. Kearns *et al.* (1945) reported that chlordan was three times as toxic as DDT to house flies and American cockroaches, but that its residual toxicity to *Anopheles quadrimaculatus* Say was not so long-lasting as that of DDT. Parker & Beacher (1947) reported that chlorinated camphene compared favorably with DDT as a residual toxicant for house flies, but that DDT paralyzed the insects more rapidly. Chlorinated camphene was also equally as toxic as DDT to adult male German cockroaches. From tests in occupied and unoccupied structures, Cutkomp (1947) found that residual deposits of DDT, benzene hexachloride, a mixture of DDT (90 per cent) and benzene hexachloride (10 per cent), chlorinated camphene, and pyrethrum retained their toxicity for 3 months or longer. He reported that under certain conditions the period of effectiveness was 1 year for DDT and benzene hexachloride and might be 3 months for chlordan.

As a contribution to this subject the present article gives the results of some of the recent laboratory and practical tests conducted at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine, in which these compounds were compared with DDT as space sprays and residual deposits against mosquitoes, house flies, and cockroaches. Gamma benzene hexachloride (95 per cent) was used in the tests with space sprays, and either the gamma isomer or technical benzene hexachloride containing 12 per cent of the gamma isomer were used in the tests of residual deposits.

Tests on Mosquitoes and House Flies. *Space Sprays.*—The space-spray tests were run in 100-cubic foot cabinets by the technique described by Lindquist and Madden (1946). The chemicals, dissolved in cyclohexanone, were sprayed into the cabinets, and a short time was allowed for the settling of the larger droplets before adult house flies, *Musca domestica* L. and yellow-fever mosquitoes, *Aëdes aegypti* (L.) were exposed to the treatments. The insects were confined in small screen-wire cages attached to a pendulum-like arrangement which was introduced through the top of the cabinet and swung back and forth in the spray mist. Following the exposure they were transferred to clean cages, furnished food (honey) and water, and held in a constant-temperature room at 80° F.

Each cage contained about 50 mosquitoes 2 to 3 days old or 35 house flies 4 days old, from laboratory-reared colonies. Four cages of each species, exposed in pairs in duplicated sprayings, were used per test, and each test was replicated several times with insects from different lots. The concentration required to give 50 or 90 per cent mortality was determined from dosage-mortality regressions computed from the data by the Bliss probit method. These values were used in comparing the toxicity of the different compounds.

In one series of tests the four chemicals were applied at five concentrations ranging from 0.25 to 5 per cent, and 1 ml. of solution was sprayed into the cabinet. After a settling time of 20 seconds, the mosquitoes were exposed for 10 seconds, followed immediately by the house flies for 2 minutes. There were 5 replicates of each treatment, thus giving totals of about 1,000 mosquitoes and 700 house flies exposed to each concentration of the different materials.

The results in table 1 show that gamma benzene hexachloride gave a much greater knock-down and kill than the other com-

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Table 1.—Knock-down and mortality of *Aëdes aegypti* and *Musca domestica* adults sprayed with different concentrations of four compounds.

Material	Per Cent Knock-Down in 30 Minutes at Concentrations of—					Per Cent Kill in 24 Hours at Concentrations of—					Concentration Giving 90 Per Cent Mortality
	0.25	0.5	1	2	5	0.25	0.5	1	2	5	
				Aëdes aegypti							
Gamma benzene hexachloride	3	18	37	91	99	74	95	99	99	100	0.40
DDT	0	3	1	4	22	34	88	88	97	100	1.00
Chlordan	0	.3	1	1	15	17	23	35	90	99	2.96
Chlorinated camphene	0	.1	.1	.2	2	16	21	27	42	72	26.96
				Musca domestica							
Gamma benzene hexachloride	54	76	95	99	100	93	99	100	100	100	.17
DDT	0	10	9	56	71	34	85	84	98	99	1.01
Chlordan	0	0	0	0	8	54	66	87	99	100	.88
Chlorinated camphene	0	0	0	.4	10	11	14	41	59	94	4.89

pounds. The concentration required to kill 90 per cent for this material was 0.17 per cent for house flies and 0.4 per cent for mosquitoes, compared with about 1 per cent of DDT for each species. With chlordan the comparable percentages were about 0.9 per cent for house flies and 3 per cent for mosquitoes, an indication that this compound was slightly more effective than DDT on house flies but less effective on the mosquitoes. Chlorinated camphene was much less toxic than these three. On the basis of 30-minute knock-down a 0.5 per cent solution of gamma benzene hexachloride was about equal to 5 per cent of DDT against each species. With the other materials the knock-down in 30 minutes was low.

In other tests in which chlordan and DDT were compared, the results differed considerably from those noted above. In these tests the materials were diluted to 0.25, 0.5, and 1 per cent, and the amount of solution used was increased to 2 ml. On one occasion eight samples of chlordan were compared with recrystallized DDT against female house flies. The insects were exposed in the cabinets for 2 minutes after a settling time of 1 minute. In each test there were three replicates. The concentration required to cause 50 per cent mortality ranged between 0.24 and 0.46 per cent for the chlordan samples, compared with 0.70 per cent for DDT. In another series, against both house flies and mosquitoes, a refined grade of chlordan was compared with recrystallized DDT. After a 1-minute settling time the house flies were exposed for 2 minutes, followed immediately by the mosquitoes for 10 seconds. In these tests there were five replicates on female house flies and three replicates on both sexes of mosquitoes. With house flies the concentration required to cause 50 per cent mortality was 0.37 per cent for chlordan and 0.86 per cent for DDT. Against mosquitoes the relative toxicities were markedly reversed, being 3.51 for chlordan and 0.28 for DDT.

Although the relative toxicities varied considerably in these tests, chlordan was always the better of the two on house flies but poorer on mosquitoes. Its toxicity to flies ranged from only slightly more than 1 to almost 3 times that of DDT. In contrast, DDT was 3 to more than 12 times as toxic to mosquitoes.

Residue Tests in the Laboratory.—The four test chemicals were sprayed on the inner surfaces of plywood boxes to compare their efficacy as residual deposits. Kerosene was used as the carrier, and the applications were made with a DeVilbiss atomizer. At various intervals after treatment about 50 mosquitoes and 50 house flies were exposed (separately) for 2 hours in the treated boxes and then transferred to untreated screen cages. The effectiveness of the treatments was judged by the knock-down at the end of 2 hours and the mortality after 24 hours.

In one series of tests the application rate was 10 mg. per square foot, four boxes being treated with each material. The flies and mosquitoes were exposed in each box on each of four consecutive days during the 1st, 4th, and 8th weeks after treatment. The mortality records in table 2 (each an average of 16 tests) indicate

Table 2.—Per cent mortality in 24 hours of flies and mosquitoes exposed for 2 hours to insecticide residues in boxes at different intervals after treatment at the rate of 10 mg. per sq. ft.

MATERIAL	*Musca domestica*			*Aëdes aegypti*		
	1 Week	4 Weeks	8 Weeks	1 Week	4 Weeks	8 Weeks
Chlordan	94	59	66	99	47	24
DDT	73	50	36	99	46	56
Benzene hexachloride, technical	63	16	21	100	49	33
Chlorinated camphene	8	1	0	41	14	20

that during the 1st week DDT and technical benzene hexachloride were about equally effective. Chlordan was equal to these two against mosquitoes and superior against house flies. After 8 weeks DDT gave the highest kill of mosquitoes but a lower kill of house flies than did chlordan. Chlorinated camphene was the least effective of the materials.

These low-dosage tests were undertaken originally to determine whether results on comparative effectiveness could be obtained in a much shorter time than that required with the higher dosages as usually employed. From this standpoint, however, the results were not consistent with those in the test discussed below.

In a second series of tests, single boxes were treated with the chemicals at rates of 50, 100, 200, and 400 mg. per square foot. During the 1st week and thereafter at intervals of about 4 weeks, up to the 36th week, one lot of house flies and one of mosquitoes were exposed in each box. At the end of this period DDT at all dosages was still causing more than 90 per cent mortality from 2-hour exposures of both test species, whereas chlordan was producing similar kills against house flies only at the highest dosage (400 mg.). Chlorinated camphene was effective against mosquitoes at both the 200- and 400-mg. dosages but was less effective against house flies. Technical benzene hexachloride, on the basis of kill, was the least durable of the four compounds, but its knockdown performance was better than that of chlordan or chlorinated camphene. The time that the different treatments caused mortality and knockdown of 90 to 100 per cent is shown in table 3.

The susceptibility of *Anopheles quadrimaculatus* was compared with that of *Aëdes aegypti* by making replicated exposures of the two species in these boxes during the 47th week after the original treatment. *A. quadrimaculatus* was somewhat the more susceptible to chlordan and chlorinated camphene, and possibly to benezene hexachloride also. The DDT treatments, however, showed little differences between the two species. The comparisons are shown in table 4.

Residue Tests in Buildings.—In an area near Sanford, Fla., naturally infested with *Anopheles quadrimaculatus* and *A. crucians* Wied., several small buildings serv-

Table 3.—Number of weeks that mortality or knock-down of 90 per cent or above was maintained by different residual deposits of four insecticides. (Deposits in milligrams per square foot.)

MATERIAL	*Musca domestica*				*Aëdes aegypti*			
	Deposit				Deposit			
	50	100	200	400	50	100	200	400
	Mortality							
DDT	36+	36+	36+	36+	36+	36+	36+	36+
Chlorinated camphene	0	9	24	28	5	9	36+	36+
Chlordan	9	13[1]	28[1]	36+	13[1]	13[1]	28	32
Benzene hexachloride, technical	0[1]	0[1]	9	9	9	9	9	24
	Knock-Down							
DDT	36+	36+	36+	36+	20[1]	20[1]	24[1]	36+
Chlorinated camphene	1	1	1	1	0	0	1	1
Chlordan	1	1	1[1]	1[1]	1	1[1]	8[1]	20
Benzene hexachloride, technical	1	1	8	1[2]	4	8	8	20

[1] One record above 90 per cent in a later test.

Table 4.—Mortality of *Aëdes aegypti* and *Anopheles quadrimaculatus* 24 hours after exposure to residual deposits of four compounds. (Four replications, 2-hour exposures. Deposits in milligrams per square foot.)

Material	50 Mg.		100 Mg.		200 Mg.		400 Mg.	
	A. quadrimaculatus	*A. aegypti*	*A. quadrimaculatus*	*A. aegypti*	*A. quadrimaculatus*	*A. aegypti*	*A. quadrimaculatus*	*A. aegypti*
DDT	85	92	96	95	98	100	100	100
Chlordan	25	25	48	20	66	42	96	81
Benzene hexachloride	7	8	5	12	12	18	54	33
Chlorinated camphene	21	11	31	20	93	51	98	84

ing as daytime resting places for these mosquitoes were treated with chlordan, technical benzene hexachloride, or DDT. The buildings were divided into two groups, one consisting of five privies near together, the other of two privies and two chicken house scattered within 1.5 miles of each other. The materials, prepared as 2.5 per cent solutions in kerosene, were applied to the inside wall surfaces of the buildings with a hand pressure sprayer. Ten per cent of cyclohexanone was added as an auxiliary solvent to the benzene hexachloride sprays. One building in each group was treated with each compound at the rate of 200 mg. per square foot, and the others were left as untreated controls. Before treatment and at weekly or bi-weekly intervals after treatment the mosquitoes resting on the walls and ceilings were counted (in the afternoons). Originally there were many more mosquitoes in the second group of buildings than in the first.

A week after treatment, as shown in table 5, no mosquitoes were present in any of the treated buildings, but within 2 or 3 weeks a few were observed resting on the walls of the four buildings treated with chlordan and benzene hexachloride. By the fourth to sixth weeks the treatments in three of these four buildings appeared to be comparatively ineffective. One of the buildings treated with benzene hexachloride, however, had only a few mosquitoes up to the tenth week, and rel-

Table 5.—Counts of anopheline mosquitoes in buildings sprayed with chlordan, technical benzene hexachloride and DDT at the rate of 200 mg. per square foot.

Weeks Before or After Treatment	Chlordan		Benzene Hexachloride		DDT		Untreated Buildings		
	Privy		Privy	Chicken House	Privy		Privy		Chicken House
	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 1	Group 2
Pre-treatment Counts									
4 (June 26)	31	—	11	—	24	—	34	17	—
3	106	—	37	—	56	—	12	5	—
2	80	684	23	865	46	592	5	4	240
1	169	565	24	1235	25	620	28	34	417
0	159	1660	13	755	44	623	3	26	226
Post-treatment Counts (Buildings Treated July 23, 1947)									
1	0	0	0	0	0	0	10	60	800
2	7	1	0	0	0	0	17	23	850
3	0	4	0	6	0	0	39	47	416
4	0	22	2	11	1	0	14	15	113
6	7	48	0	110	0	0	4	21	28
7	50	215	4	56	0	0	31	73	96
9	0	134	0	134	0	0	0	0	49
10	3	58	0	17	0	0	22	9	33
11	82	70	14	77	2	0	36	66	221
12	120	66	6	136	4	0	80	24	282
13	115	228	4	190	3	2	100	116	385
14	80	260	3	220	2	2	92	118	240
15 (Nov. 7)	17	34	3	169	0	3	40	22	89

atively small numbers for several weeks afterwards. In the DDT-treated buildings only one mosquito was found during the first 10 weeks, and the numbers remained very low up to the fifteenth week when the observations were discontinued.

TESTS ON COCKROACHES. *Laboratory Tests.*—The four compounds were tested as residual-type treatments against the American and German cockroaches, *Periplaneta americana* (L.), and *Blatella germanica* (L.), by exposing the insects on pieces of cotton twill cloth (6 inches square) that had been impregnated with acetone solutions of the test material at the rate of 200 mg. per square foot. The cloths were stapled to plywood boards and stored at room temperature when not in use. Triplicate panels were prepared for each material. Adult cockroaches, in lots of five, were confined on the cloths for 2 hours and then transferred to clean battery jars and provided with water. Each sex of each species was confined separately under half sections of petri dishes. Observations on the toxicity of the compounds were made on the 1st, 7th, and 28th days after treatment. These results are summarized in table 6.

Gamma benzene hexachloride was the best of the materials during the 1st week and was outstanding on 5-hour knock-down, but it had lost most of its toxicity by the 28th day. Chlordan was effective when fresh and was somewhat more lasting than the other materials, although it was not highly effective after 28 days. DDT and chlorinated camphene did not give high kills from 2-hour exposures even when freshly applied.

The American cockroach appeared to be somewhat more resistant than the German cockroach to gamma benzene hexachloride and chlordan, but showed less resistance to DDT. In the tests that showed a mortality of 25 per cent or more, the kill of the males was usually higher than that of the females.

Table 6.—Toxicity to American and German cockroaches of four compounds applied as residue treatments on cotton twill.

Age of Residue (Days)	Per Cent Knock-Down in 5 Hours				Per Cent Kill in 48 Hours			
	American		German		American		German	
	Males	Females	Males	Females	Males	Females	Males	Females
	Gamma Benzene Hexachloride (95 Per Cent)							
1	100	100	100	100	100	93	100	100
7	100	40	100	100	100	60	100	100
28	0	0	20	0	7	7	20	20
	Chlordan							
1	0	0	53	20	100	100	100	100
7	0	0	7	0	17	20	100	73
28	0	0	0	0	20	47	87	53
	DDT							
1	17	7	7	0	67	7	13	0
7	20	0	0	0	73	13	53	13
28	0	0	0	0	33	13	7	0
	Chlorinated Camphene							
1	0	7	0	0	33	40	13	20
7	0	0	0	0	13	13	40	13
28	0	0	0	0	0	7	7	0
	Checks (Untreated)							
1	0	0	0	0	25	20	0	7
7	0	0	0	0	0	13	0	0
28	0	0	0	0	0	7	13	7

Building Tests.—Solutions of chlordan and gamma benzene hexachloride were applied with a hand pressure sprayer to the walls of three kitchens in houses infested with cockroaches. Two rooms were treated with chlordan and one with gamma benzene hexachloride, each at the rate of 100 mg. per square foot. The sprays contained 1.25 per cent of the toxicant dissolved in kerosene. Prior to treatment the cockroach adults and large nymphs visible in the kitchens were counted on several occasions, some counts being made in the daytime and others at night. Particular attention was paid to cracks, cupboards, sinks, ice boxes, and

the under portions of chairs and tables. Post-treatment counts were made each week for 4 weeks, and again on the 8th week.

Table 7 shows the pre- and post-treatment counts obtained in each of the kitchens. Dead cockroaches were collected in all the houses for several days after spraying. At the end of 8 weeks no live ones were observed in the two houses treated with chlordan. In the house sprayed with gamma benzene hexachloride absence of German cockroaches, therefore, seems to be attributable to lack of reinfestation.

A thermal fog generator was used to treat four negro dwelling houses that were badly infested with cockroaches (principally *B. germanica*, with a small proportion of *P. americana*). In three of them a kerosene solution containing 10 per cent of DDT, 2.5 per cent of chlordan, and 10 per cent of cyclohexanone was dispersed at rates of 0.07 to 0.2 gallon per 1000

Table 7.—Number of live cockroaches in kitchens sprayed with gamma benzene hexachloride and chlordan at the rate of 100 mg. per square foot.

Date	Chlordan				Gamma Benzene Hexachloride	
	Room 1		Room 2			
	American	German	American	German	American	German
	Pre-treatment Counts					
June 24[1]	—	—	0	66	17	46
July 1[1]	—	—	0	217	31	52
7	0	301	0	65	35	62
7[1]	49	181	0	282	59	82
8	7	356	0	79	33	57
9	0	353	0	139	56	46
	—	—	—	—	—	—
Averages	14	299		133	39	58
	Post-treatment Counts (Kitchens Treated July 9, 1947)					
July 16	0	12	0	6	2	0
16[1]	2	10	0	3	14	0
23	0	0	0	2	12	0
23[1]	2	2	0	2	14	0
30	0	4	0	3	19	0
Aug. 6	0	0	0	3	25	0
Sept. 3	0	0	0	0	30	0

[1] Night time counts.

no German cockroaches were found, but the number of the American species was nearly equal to the pre-treatment average. It was the only one of the three houses that had an appreciable number of the American species at the time of treatment and apparently was subject to reinfestation from harboring places in the yard.

Eight weeks after treatment 15 male German cockroaches, 5 in each of 3 petri dishes, were exposed for 2 hours on the walls of each of these kitchens to determine whether an effective residue remained. In one of the rooms sprayed with chlordan a mortality of 47 per cent in 48 hours was obtained, but in the other none of the insects were killed. In the kitchen treated with gamma benzene hexachloride the kill was only 13 per cent. From these results it appeared that the residues were not highly effective. The

cubic feet. The fourth house was treated with 20 per cent of DDT and 20 per cent of cyclohexanone in kerosene at the rate of 1.4 gallons per 1000 cubic feet, and 11 days later with a 5 per cent solution of chlordan in kerosene. The fogs were applied through open doors or windows, and as far as possible all other openings were shut. However, the buildings were in poor repair and could not be closed completely.

In the three houses treated with the DDT-chlordan mixture, many dying or dead cockroaches of both species were found daily during the following 3 days. Live cockroaches were very difficult to find during the first week, but from 7 to 24 of the German species were observed in one of them during five examinations the second week. Only one was found the third week. Dead cockroaches were collected occasionally from the floor during

both the second and third weeks. The infestation remained at a very low level for at least 3 months.

In the house treated with the DDT fog containing no chlordan, 46 dead cockroaches were found when the 24-hour check was made, but the house remained heavily infested throughout the 10-day post-treatment observation period. A total of 142 German cockroaches were counted behind a kitchen door a few minutes before the DDT was used. Three days later the number had decreased to 4, but on the 7th day it had increased again to 55. More than 200 of this species were counted in various parts of this house the day before it was retreated with chlordan. Following this treatment the floor was littered with dying cockroaches and only 4 live ones were found behind the previously mentioned door. After the 3rd day no live cockroaches were observed, but an occasional dead individual was seen. No reinfestation was noticeable 55 weeks later.

SUMMARY.—The relative effectiveness of chlordan, benzene hexachloride, chlorinated camphene, and DDT as space and residual sprays against adult mosquitoes, *Aëdes aegypti* (L.), and *Anopheles quadrimaculatus* Say, house flies, *Musca domestica* L., and cockroaches, *Periplaneta americana* (L.), and *Blatella germanica* (L.), was studied in laboratory and practical tests. In the space spray-tests, gamma benzene hexachloride (95 per cent) was about six times as toxic as DDT to *M. domestica* and two and a half times as toxic to *A. aegypti*. With chordan, although different samples varied in effectiveness, all samples were more toxic than DDT to house flies but less so to mosquitoes. Chlorinated camphene was considerably less effective than the other three materials against house flies and very much less so against mosquitoes.

When these four compounds were tested as residues on plywood surfaces at dosages of 50, 100, 200, and 400 mg. per square foot, DDT was the only one still causing high mortalities of house flies and mosquitoes, *Aëdes aegypti*, at the end of 36 weeks at all dosages.

Similar results were obtained when DDT, chlordan, and technical benzene hexachloride were applied at the rate of 200 mg. per square foot to the walls and ceilings of small outbuildings serving as resting places for *Anopheles quadrimaculatus*. Few mosquitoes were found in the buildings during the first 2 or 3 weeks after treatment, but in those treated with chlordan and technical benzene hexachloride increasing numbers occurred after 4 weeks. The numbers remained low in the DDT-treated buildings until the observations were terminated 15 weeks after treatment.

Anopheles quadrimaculatus and *Aëdes aegypti* were found to be about equally susceptible to deposits of DDT, but *Anopheles quadrimaculatus* was more susceptible to the other three compounds.

In laboratory tests on adult cockroaches gamma benzene hexachloride (95 per cent) and chlordan were both highly effective for 1 to 7 days after application as residual treatments, and the former was outstanding in speed of knock-down. DDT and chlorinated camphene were relatively ineffective when freshly applied, and none of the materials gave a high mortality after 4 weeks of aging.

Chlordan and gamma benzene hexachloride sprayed at the rate of 100 mg. per square foot on the walls of kitchens infested with *Blatella germanica* eliminated a high proportion of the roaches, and the rooms did not become reinfested with this species during the subsequent observation period of 8 weeks.

Solutions of chlordan and a mixture of chlordan and DDT, when dispersed by means of a thermal fog generator, effectively controlled cockroaches, but a similar treatment with DDT alone was much less successful.—6-12-48.

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SCIENTIFIC NOTES

Resistance of House Flies to Residual Applications of DDT in New Jersey[1]

ELTON J. HANSENS, JOHN B. SCHMITT, and GEORGE W. BARBER, *Rutgers University, New Brunswick, N. J.*

During the summer of 1948 many instances of unsatisfactory control of house flies in barns following the application of residual DDT sprays came to our attention. Six barns in Hunterdon County were selected for study. The measures for fly control that had been applied to these barns were as follows:

Barn 1: Sprayed in June with cold water paint containing 4 per cent DDT, and in early August with cold water paint containing 6 per cent DDT. House flies were very abundant in late August.

Barn 2: Sprayed in June and on August 18 with 5 per cent DDT emulsion. House flies were plentiful in the barn in late August. A pig pen similarly sprayed was heavily infested.

Barn 3: Although well screened and provided with electric door screens, 50 per cent DDT wettable powder applied at the rate of 20 pounds per 100 gallons of water failed to control house flies. Applications were made in early June and on August 1.

Barn 4: Sprayed in June with cold water paint containing 4 per cent DDT. Two weeks later it was apparent that control had not been obtained, and periodic spraying with 5 per cent DDT emulsion of favored resting places was continued through the summer. House flies were plentiful in late August.

Barn 5: Sprayed in June with 5 per cent DDT emulsion and with 50 per cent wettable DDT powder on August 7. House flies were not abundant in late August.

Barn 6: Sprayed three times in June and on August 19 with 5 per cent DDT emulsion, and in July with wettable powder. House flies were not abundant in late August.

House flies were captured in each of these barns and brought into the laboratory to determine whether they were resistant to DDT residues. They were tested by the methods described by Barber and Schmitt (1948), who demonstrated resistance to DDT and related compoundsby house flies reared from wild flies taken in a resort hotel. The reactions of flies captured in the mentioned barns were compared with those of the line of laboratory flies used previously. Data for these tests are given in table 1.

These data show much resistance to DDT residues in flies from barns 1, 2, and 3, and less resistance in flies from barns 4, 5, and 6, as compared with flies of the standard laboratory colony. All flies collected in barns, as well as those from the laboratory colony, were killed in tests using residues of chlordan, chlorinated camphene, parathion and tetraethyl pyrophosphate at the same rate.

SUMMARY.—Flies from six barns in New Jersey

[1] Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.

Table 1.—Comparison of percentage kill after 24 hours of flies collected in 6 barns when exposed to DDT residues at a concentration of 144 mgm/sq. ft.

PERCENTAGE OF FLIES FROM THE STATED SOURCES KILLED BY EXPOSURE TO INSECTICIDES FOR THE FOLLOWING TIMES

Source of Flies	Untreated		30 minutes		1 hour		2 hours	
	Flies Number	Dead Per cent	Flies Number	Dead Per cent	Flies Number	Dead Per cent	Flies Number	Dead Per cent
DDT (technical)								
Collected Barn #1	70	2.9	57	12.3	62	60.0	39	97.4
#2	81	3.7	24	4.2	53	77.4	43	65.1
#3	35	0	10	10.0	42	50.0	36	66.7
#4	12	0	—	—	31	96.8	—	—
#5	29	3.4	—	—	18	100.0	—	—
#6	16	0	—	—	17	94.1	—	—
Laboratory Colony	23	26.1	—	—	34	100.0	—	—
pp′ isomer of DDT								
Collected Barn #1	70	2.9	15	13.3	79	65.8	47	100.0
#2	81	3.7	11	13.2	43	41.9	33	100.0
#3	35	0	11	9.1	41	22.0	33	100.0
#4	12	0	—	—	22	72.7	—	—
#5	29	3.4	—	—	14	78.6	—	—
#6	16	0	—	—	11	54.5	—	—
Laboratory Colony	23	26.1	—	—	51	100.0	—	—

which had been carefully sprayed with DDT were examined for resistance to this insecticide, using methods previously employed. Marked resistance to technical DDT and the para-para isomer was found in flies from three barns and less resistance was found in flies from the other barns. All flies of the standard laboratory colony that were used for comparison were killed by the DDT residues. All flies, irrespective of source were killed by residual sprays of chlordan, chlorinated camphene, parathion, and tetraethyl pyrophosphate.

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Preliminary Field Tests with New Insecticides for Control of Velvetbean Caterpillar

F. S. ARANT, *Alabama Agricultural Experiment Station, Auburn*

Preliminary experiments to measure effectiveness of new insecticides in control of the velvetbean caterpillar, *Anticarsia gemmatilis* (Hbn.), were conducted on alfalfa and soybeans in Alabama during 1946 and 1947.

In 1946, a very simple test was performed on alfalfa to determine the effectiveness of three insecticidal dusts formulated with inert diluents. One application of each dust was made at the rate of 15 pounds per acre to plots 0.25 acre in size. Treatments were not replicated, but each dusted plot was paired with an undusted check. Results of the experiment are presented in table 1. One per cent DDT and 1 per cent Gamma benzene hexachloride were highly effective. One per cent chlordan was less effective.

In 1947, tests were conducted on soybeans. Two blocks of plots were used in the experiment. Plots were four rows wide and 40 feet long. The two blocks of plots were separated by 12 buffer rows. In each block, the first plot and every third one thereafter served as an undusted check. Dusting treatments were then randomized in the remaining plots of each block. Thus, two adjoining dusted plots were located between undusted checks throughout each block.

Eight insecticidal dusts formulated with inert diluents were applied to duplicate plots at the rate of 25 pounds per acre. Each dust was weighed to the nearest .01 pound, placed in a small plunger-type gun, and dusted lightly over the plot until the gun was empty.

Effectiveness of treatments was measured by counting the number of live larvae per 10 feet of soybean row at the end of 24 and 48 hours. Infestation on each dusted plot was compared with that of the checks on either side, and the per cent control was calculated by Abbott's (1925) formula.

Results of the experiment are presented in table 2. With the exception of 5 per cent chlordan, all treatments gave satisfactory control. The new organics were faster in action than cryolite, chlordan again excepted.

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Table 1.—Velvetbean caterpillar on dusted and undusted alfalfa, 1946.

DUST USED	AVERAGE NO. LARVAE PER 5 SWEEPS OF INSECT NET				
	Before Dusting	1 Day After Dusting	3 Days After Dusting	9 Days After Dusting	14 Days After Dusting
DDT, 1%	39.0[1]	25.2	7.2	2.0	0.5
Check	35.5[1]	56.7	44.5	87.0	52.0
Benzene hexachloride, 1% Gamma	30.0[1]	6.2	4.0	1.5	2.0
Check	28.0[1]	35.0	40.2	77.5	50.0
Chlordan, 1%	79.5	—	39.0	27.5[2]	
Check	61.5	—	53.0	53.5[2]	

[1] Larvae on area 2 feet square, rather than from 5 sweeps of net.
[2] Five days after dusting.

Table 2.—Average control of velvetbean caterpillar on soybeans, 1947.

INSECTICIDE	24 HRS. AFTER DUSTING			48 HRS. AFTER DUSTING		
	No. Larvae/10 Ft.			No. Larvae/10 Ft.		
	On Checks	On Dusted	Per Cent Control[1]	On Checks	On Dusted	Per Cent Control[1]
Cryolite	67.3	23.5	65.1	74.5	9.5	87.2
DDD, 5%	66.3	5.5	91.7	71.8	0.5	99.3
Methoxy DDT, 5%	67.0	5.5	91.8	73.0	1.0	98.6
Chlordan, 5%	66.0	45.5	31.1	70.3	22.5	68.0
DDT, 2%	73.0	3.0	95.9	80.7	0.5	99.4
Parathion, 1%	73.3	3.5	95.2	84.7	4.0	95.3
Chlorinated camphene, 10%	79.0	2.0	97.5	84.5	0.0	100.0
Benzene hexachloride 1% Gamma	79.3	9.5	88.0	88.5	2.0	97.7

[1] Abbott's formula: Per cent control $= \frac{\text{No. insects on check} - \text{No. on dusted}}{\text{No. insects on check}} \times 100.$

A Successful Large-Scale Experiment in Methyl Bromide Fumigation of Bulk Cottonseed for Pink Bollworm Control

G. L. PHILLIPS and W. G. BODENSTEIN, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The managers of a cottonseed oil mill in Oklahoma City recently requested consideration by the Bureau of Entomology and Plant Quarantine of their proposal to fumigate bulk cottonseed with methyl bromide in lieu of sterilization by heat, as required by pink bollworm quarantines. Experimental studies have already proved that pink bollworm larvae embedded in cottonseed can be killed with moderate dosages of methyl bromide, provided the fumigant can be properly distributed. The mill representatives proposed to fumigate bulk cottonseed in a large steel tank originally built for drying seed. The tank was equipped with a powerful blower to draw air down through the mass of seed. The representatives maintained that methyl bromide could be thoroughly distributed by this system.

Three tests were made between March 2 and 16 at Oklahoma City, with the Southland Cotton Oil Company and the Dow Chemical Company participating.[1]

EQUIPMENT.—The tank in which the fumigation tests were made was cylindrical, with an inside height of approximately 48 feet, a diameter of 38 feet and 8 inches, and a capacity of 56,345 cubic feet. The tank was constructed of 4- by 8-foot steel plates bolted together, with rubber gaskets between them. Openings into the tank consisted of entrance and loading ports and a 12-inch screw conveyor used in unloading. All these parts except the unloading conveyor were sealed by metal plates during fumigation. The air-circulating system consisted of a 40-inch centrifugal fan of the mill-exhauster type, located outside the base of the tank; two 8-inch laterals to withdraw air from beneath the perforated false floor; and a 16-inch return duct, which carried the air from the blower to the top of the tank. The fan was driven at 1750 r.p.m. by a 50 h.p. electric motor, and had an estimated capacity of 6000 to 8000 cubic feet per minute. Circulation of air through a load of 550 tons of cottonseed was established within 5 to 8 minutes, as determined by pressure readings above and below the load of seed.

EXPERIMENTAL TECHNIQUE.—The distribution of gas was studied by placing 45 samples of infested cottonseed at various points throughout the load, and by sampling the gas at intervals at several locations. Each biological sample consisted of 8 ounces of infested seed cotton contained in a cloth sack, which in turn was wrapped in screen wire for protection. In the first test the samples were fastened at 5-foot intervals to 50-foot lengths of chain, 9 samples being placed on each chain. Five such chains were suspended from the top of the chamber at the center, at 5, 10, and 15 feet from the center, and against the outer wall. The lowest sample was at floor level. (Pressure created by the load caused several of the chains to break, and in the succeeding tests a different procedure was followed.)

In the second and third experiments eight 22-foot lengths of chain were prepared, with 5 samples attached to each at 5-foot intervals. Each chain was attached by one end to a pillar at the center of the tank, the points of attachment being 5 feet apart, beginning 8 feet above the floor. As loading proceeded and the cone of seed reached the level of a chain attachment, that particular chain was laid down the pile, so that the last sample reached the wall of the tank. The chains were placed in different directions from the center, so that the samples covered different sectors of the load at different levels. Five samples were laid at random on the floor of the chamber in order to have samples representative of all sections of the load.

In the first test representatives of the Dow Chemical Company added 15 cages of flour beetle adults and carpet beetle larvae. These were distributed in 3 cages per chain, placed at 15-foot intervals.

Six points in the load were sampled through lengths of plastic tubing attached to the chains at the location of certain insect samples, and additional samples were taken by removing bolts and inserting lengths of tubing into the seed. The mixture of air and gas was drawn from the tank by means of evacuated bottles and was analyzed by means of ethanolamine hydrolysis and bromide determination by the Volhard method (Stenger *et al.*, 1939).

PROCEDURE.—Approximately 3 days were required to fill the tank with 450 to 550 tons of cottonseed. When the load had reached the desired level all openings were closed and sealed, the blower was started, and the tank and circulating system were checked for leaks. In each experiment air circulation was established before the introduction of the gas by running the blower 10 minutes. The gas was released from a cylinder directly into the circulating system at a point just above the blower. When released in this manner a 175-pound cylinder required 6 to 7.5 minutes to complete discharge, and the gas first appeared at the bottom of the load in 4 to 6.5 minutes after introduction was begun. The blower was operated 10 minutes after all the gas had been released, to mix the fumigant with the air in the tank.

[1] The oil mill was represented by John Pearson, superintendent, and E. R. Smith; the Dow Chemical Company by John Peterson and Marc Wolfe.

Table 1.—Conditions under which methyl bromide was distributed throughout three 24-hour tests.

Test No.	Load (Tons)	Dosage (Pounds/1,000 Cubic Feet	Temperature (°F.)			Wind (M.p.h.)
			Wall Seed	Center Seed	Outside Air	
1	550	3.0	48–55	62–65	30–48	15–25
2	550	6.0	41	60	38–40	12
3	450	4.5	46–62	62	42–73	30

Gas samples were taken at intervals after the introduction of the gas. At the end of the exposure period the exhaust vent was opened and the blower operated 8 to 12 hours, until no trace of gas was evident in the exhaust stream. Insect samples were removed as the seed was unloaded over a period of 2 to 3 days.

Dosage rates of 3 pounds of methyl bromide per 1000 cubic feet (the authorized dosage for fumigation of sacked cottonseed in metal-lined chambers), 4.5, and 6 pounds were used (Table 1). For practical purposes a 175-pound cylinder was applied as a 3-pound per 1000 cubic feet dosage, although actually it was slightly in excess of this rate. The other applications were in multiples of 175 pounds. The exposure period was 24 hours for each fumigation.

RESULTS.—Both the gas sampling and the mortality resulting in the insect samples showed the distribution of methyl bromide throughout the loads to be satisfactory.

Gas analysis determined that within 1 hour after the start of the fumigation, at least 55 per cent of the applied dosage was found at all points sampled. In general, the concentrations tended to fall gradually until the end of the exposure. Two hours after the start the concentration ranged from 31.5 to 87.5, from 50 to 69.5, and from 55 to 75 per cent of the applied dosage, respectively, in the three tests. After 24 hours the concentrations in the same tests ranged from 17.5 to 58, from 15.5 to 40, and from 14.5 to 45 per cent, respectively.

All the treatments resulted in 100 per cent mortality of the insects in all the biological samples.

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The Orange Tortrix, a Pest of Raspberries in Western Washington[1]

E. P. BREAKEY[2] and G. S. BATCHELOR[3]

The orange tortrix, *Argyrotaenia citrana* (Fernald), has been a troublesome pest in the orange groves of California for many years. Prior to 1933, it was known to be a greenhouse pest in western Washington. By 1933, it began appearing in certain raspberry fields near Seattle where it was known as the "bush worm." In 1938, Mr. M. J. Forsell of Seattle obtained a moth from one of these larvae and it was determined for him as the orange tortrix. Loganberries on Vashon Island were rather seriously infested by these worms in 1939, and at least one raspberry field near Puyallup reported a fair number. Additional reports of the presence of the insect were received during 1940, and larvae were collected in three blackberry fields that fall. The insect has continued to spread throughout western Washington until it has become the number one problem of the berry growers in this area.

The larvae are primarily foliage feeders though they are also known to feed on the flowers and on the ripening fruit. Objection to their presence in the field arises primarily from the fact that they appear in the processing plants as a contamination of the fruit. During the summer months, they can be found in the terminal growths of the canes, where they usually tie some of the leaves together forming the shelters in which they do most of their feeding. When disturbed, they will wiggle out of their shelters and drop toward the earth on a web. If a berry picker has placed his stand under one of these shelters, the caterpillar may come to rest among the fruits in the cups where it will hide among the berries and go to the cannery.

During 1941 and 1942, attempts were made to control the pest with insecticides, testing the effectiveness of those available at that time, particularly those in use against the raspberry fruit worm, *Byturus bakeri* Barber, since it was hoped both pests could be controlled with the same program. Cryolite, the standard control used in California, proved to be quite effective, though its use will probably be restricted by the danger of building up a poisonous residue on the fruit.

By 1946, the insect had become a serious problem for the raspberry growers in the Puyallup Valley. Berries from 125 acres were refused by the processors in Pierce County alone in 1947, representing a loss of approximately $150,000, and several growers lost their entire crops.

During the summer of 1947, some of the newer insecticides were tested against cryolite as controls for the orange tortrix. Dichloro diphenyl dichloroethane was the most promising of the new materials tested. Many growers used the highly publicized DDT. The results were disastrous to many, for the Willamette mite, *Tetranychus willamettei* McGregor, became a serious problem in most plantings where DDT had been used. Moreover, DDT also failed to control the orange tortrix and proved to be toxic to the raspberry plants. Unfortunately, the use of dichloro diphenyl trichloroethane may also encourage the development of the mites though it gives promise as a control for the orange tortrix and is apparently less toxic to the raspberry plants. It gives a quicker kill of the larvae and promises to provide a more positive control for the pest under climatic conditions prevailing in this area.

SEASONAL HISTORY.—The larvae of the orange tortrix can be found in the field every month of the year. The insect winters in the larval stage. These larvae prefer to feed on the buds and tenderest leaf growth. During the summer months, they can be found in the terminal growths of the canes where they usually tie some of the leaves together, forming the shelters in which they do most of their feeding.

Eggs are laid in masses of 30 to 35 (average) on the leaves of the host plants. These egg masses can be found in greatest numbers near the crate sheds. Apparently, many of the larvae that are carried in from the field escape near the shed. It is probably in this way that the insect is concentrated near the sheds.

There are several generations of the insect each year. Larvae from the same egg mass are known to develop at greatly different rates. This may account for the fact that there are no clean cut generations, all stages of the insect being present most of the time. Some damage doubtless results from the feeding on the flowers and flower buds. The lower temperatures of winter merely slow down the development of the pest. Overwintering larvae feed on the cane buds and may thus do considerable damage.

[1] Published as Scientific Paper No. 809, College of Agriculture and Agri. Expt. Stations, State College of Washington.
[2] Associate Entomologist, Agri. Expt. Stations.
[3] Assistant in Entomology, Agri. Expt. Stations.

Table 1.—Control of orange tortrix on raspberries, George Richter's place, Puyallup, Washington, 1947.

Treatment	Larvae per Replicate		Total per Treatment
Dichloro diphenyl dichloroethane—2 lbs. plus 1 qt. summer oil emulsion per 100 gallons	1	2	
	2	3	9
	3	1	
	4	3	
Cryolite—2 lbs. plus 1 qt. summer oil emulsion per 100 gallons	1	5	
	2	3	18
	3	3	
	4	7	
Dimethoxy trichloroethane—2 lbs. plus 1 qt. summer oil emulsion per 100 gallons	1	4	
	2	6	19
	3	3	
	4	6	
DDT—2 lbs. plus 1 qt. summer oil emulsion per 100 gallons	1	15	
	2	10	59
	3	22	
	4	12	
Benzene hexachloride—2 lbs. plus 1 qt. summer oil emulsion per 100 gallons	1	16	
	2	15	80
	3	27	
	4	22	
Check	1	23	
	2	31	107
	3	28	
	4	25	

Host Plants.—The orange tortrix is known to feed on more than 50 plants, including various weeds and shrubs. Some of the better known host plants are the raspberry, blackberry, loganberry, boysenberry, strawberry, blueberry (flowers and tender spring growth), pyrocanthus, apple, peach, plum, cherry (sweet), grape, holly, rose, Oregon grape, salmon berry, pigweed, lambsquarter, and many others.

Brushy fence rows and neglected ditch and creek banks will doubtless be a factor in controlling the pest. Such areas are a reservoir for moths that may fly to nearby fields and lay eggs.

Insecticide Tests.—The following materials were tested against cryolite (natural) as controls for the orange tortrix during the summer of 1947: DDT; DDD (dichloro diphenyl dichloroethane); dimethoxy trichloroethane; and benzene hexachloride, 10 to 12 per cent gamma isomer. All chlorinated hydrocarbons had been formulated as spray powders containing 50 per cent of the insecticide. The sprays were prepared to contain 2 pounds of the spray powder per 100 gallons. One quart of a summer oil emulsion was added to each 100 gallons of the prepared spray for a sticker to off-set the effects of the frequent rains occurring during the season. Application was with a power sprayer using berry guns.

Each treatment was replicated four times, and each replicate consisted of one row (about 140 feet long) protected by a buffer row on each side. Though the population seemed to be fairly uniformly distributed, the treatments were randomized in an effort to off-set any irregularities that might exist. The sprays were applied on April 2, 14, and 28, and on May 12. By May 12, the raspberries had started to blossom and spraying was discontinued because of the danger of building up poisonous residues on the fruit. Counts were made on July 25. A determined effort was made to locate all larvae present on that date. It was noted that the larvae tended to be concentrated toward the ends of the rows nearest Clark's Creek, the banks of which were lined with a brushy growth. Many larvae were also noted on weeds, particularly the lambsquarters (*Chenopodium* sp.). One additional picking of fruit was made after this date.

The results of these tests have been summarized in table 1. These results are largely self-explanatory. DDD was the most promising of the new materials tested. More recent experience in its use indicates that it is unwise to use oil with the DDD since some growers have reported the development of a chlorosis as a result.

Tests in 1947 Against the Two-spotted Spider Mite[1]

FRANKLIN SHERMAN, III and HERMAN L. KING,
Michigan State College, East Lansing

During the 1947 season Michigan orchardists were troubled with a rather generalized infestation of the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, on fruit trees. This infestation, while more severe on apples, appeared also on peach, pear, and cherry trees. Where the infestation was heavy, considerable injury to the foliage and fruit was apparent. This is the first known generalized outbreak on fruit by this pest in Michigan for many years.

Unlike the European red mites, the two-spotted spider mites do not winter in the egg stage on the twigs and branches. Instead, with the coming of cool weather, the two-spotted mites change their color from pale green to a salmon color and migrate from the leaves, fruit and smaller twigs to the larger branches and the trunk, where they cluster in colonies of many individuals beneath bark flakes. Many individuals also cluster about the base of the trees and in any protective shelter they can find in the orchard cover. These hibernating habits preclude the successful use of the dormant sprays that are effective against the European red mite and necessitate the use of summer treatments.

Table 1.—Control of two-spotted spider mite on apple in Reister Orchards, Peach Ridge, Michigan. Treatments made July 29, 1947 and counts made August 1, 1947.

Material in 100 Gallons	Live Mites: Per 100 leaves	Live Mites: Maximum per leaf	Live Mites: Minimum per leaf
2.5 lbs. 25% parathion[2]	18	3	0
0.5 pint tetraethyl pyrophosphate[3] plus 0.5 pint spreader[4]	96	7	0
0.25 pint tetraethyl pyrophosphate[3] plus 0.5 pint spreader[4]	193	17	0
1 pint hexaethyl tetraphosphate[5] plus 0.5 pint spreader[4]	375	21	0
Check, unsprayed	2900	47	4

Beginning on July 29, 1947, six series of single-spray test applications were made on apples. Applications were made from two sides of the trees, with high pressure orchard sprayers, and the trees were quite thoroughly drenched. Detailed counts were made on three of the test series and field observations were made on the other three series. Counts were made by examining, w th a binocular microscope, 100 leaves selected from each of three trees in each test group. Leaves that showed mite damage were selected for the counts. This avoided the inclusion of leaves that had been uninfested or only slightly infested at the time of treatment. Results of the counts are tabulated below. Observations in the other three test series indicated that the results were similar to those in the "counted" series.

With the exception of the bis(*p*-chlorophenoxy) methane, all the materials tested gave considerable kill of mites. Parathion was the most effective material tested. It gave, with a single application, control closely approximating 100 per cent, and it left a residue that killed the mites as they hatched. With the other materials, it was evident that additional applications would be required to destroy mites hatching after the treatment.

The dicyclohexylamine salt of dinitro-*o*-cyclohexyl phenol has been used for several years for summer applications against European red mite in Michigan. At the suggestion of the manufacturer alum and aluminum sulfate were used as adjuvants with it. These materials have been found to increase its effectiveness against the European red mite. Al-

Table 2.—Control of two-spotted spider mite on apple in Reister Orchards, Peach Ridge, Michigan. Treatments made August 6, 1947 and counts made August 9, 1947.

Materials in 100 Gallons	Live Mites: Per 100 leaves	Live Mites: Maximum per leaf	Live Mites: Minimum per leaf
1.25 lbs. bis(*p*-chlorophenoxy) methane[6]	3500	75	0
2.5 lbs. bis(*p*-chlorophenoxy) methane	3200	69	0
2.5 lbs. 25% parathion[2]	50	1	0
0.5 pint tetraethyl pyrophosphate[3] plus 0.5 pint spreader[4]	53	3	0
1.25 lbs. 20% dicyclohexylamine salt of dinitro-*o*-cyclohexyl phenol[7] plus 0.5 lb. alum	100	11	0
Check, unsprayed	4000	76	7

Table 3.—Control of two-spotted spider mite on apple in Robinette Orchards, Grand Rapids, Michigan. Treatments made August 22, 1947 and counts made August 23, 1947.

Material in 100 Gallons	Live Mites: Per 100 leaves	Live Mites: Maximum per leaf	Live Mites: Minimum per leaf
1 pint hexaethyl tetraphosphate[5] plus 0.5 pint spreader[4]	1172	58	0
0.5 pint tetraethyl pyrophosphate[3] plus 0.5 pint spreader[4]	104	3	0
4 lbs. 15% parathion[2]	48	4	0
1.25 lbs. 20% dicyclohexylamine salt of dinitro-*o*-cyclohexyl phenol[7] plus 0.5 lb. aluminum sulfate	341	41	0
Check, unsprayed	10460	136	48

[1] Published by permission of the Director of the Michigan Agricultural Experiment Station. Journal Article Number 922 n.s.

[2] *Thiophos 3422*, American Cyanamid Company.

[3] Experimental lot. Niagara Sprayer and Chemical Company.

[4] Grasselli, Spreader, E. I. DuPont de Nemours and Company.

[5] *Vapotone*, California Spray Chemical Company.

[6] *C-726*, Dow Chemical Company.

[7] *DN-111*, Dow Chemical Company.

though it gave fair control of the two-spotted mite, it was obvious that two or more applications would be required for control.

Tetraethyl pyrophosphate, at a concentration of 0.5 pint per 100 gallons, gave as good control as the dinitro spray, but hexaethyl tetraphosphate, at a concentration of 1 pint per 100 gallons was less effective.

None of the materials tested caused detectable injury to the trees in 1947.

SUMMARY.—In six series of single-spray tests conducted in Michigan apple orchards, parathion gave outstanding control of the two-spotted spider mite. Used as a summer spray at the rate of 2.5 pounds of 25 per cent wettable powder, or the equivalent concentration of 15 per cent wettable powder, this material killed practically all of the mites present at the time of application and left a residue which killed mites hatching after the treatment. The dicyclohexylamine salt of dinitro-*o*-cyclohexyl phenol, tetraethyl pyrophosphate and hexaethyl tetraphosphate were somewhat less effective than parathion and did not exhibit any residual effect. Bis(*p*-chlorophenoxy) methane was ineffective. —6-23-48.

Comparison of Insecticides for Control of Harlequin Bugs[1]

J. C. GAINES and H. A. DEAN,
Texas Agricultural Experiment Station, College Station

Large numbers of adult harlequin bugs, *Murgantia histrionica* (Hahn), emerge from hibernation in central Texas early in April and cause severe injury to such crops as cabbage, turnips, etc. By control of these overwintering adults, the crops are protected and later broods may be eliminated. Vegetable planters have experienced considerable difficulty in obtaining effective control of this pest, especially the adult stage. The tests herein reported were conducted at College Station, during 1947 and 1948, to determine the relative toxicity of several insecticides when used against the overwintering adults.

LABORATORY TESTS.—Samples of approximately 40 field-collected adult harlequin bugs were placed in a suitable glass container while being dusted. An overhead dusting chamber, 9.5 inches in diameter and 40 inches high, was used for the tests. To obtain comparable distribution of dusts in the chamber, an air blast pump was used to force the dust through a glass nozzle. Glass slides which had been weighed were placed in the bottom of the chamber to determine the exact amount of each dose of insecticides which would settle in a 30-second period. After the insects were dusted, they were immediately transferred to clean jars and given clean food each day for 5 successive days. The dead bugs were recorded at 24-hour intervals. Various dosages of each material, calculated to an acre basis, were applied. This entailed the use of approximately 200 individuals to determine each toxicity curve. After treatment the bugs were kept at 75° to 85° temperature and 60 to 70 per cent relative humidity during the observation period.

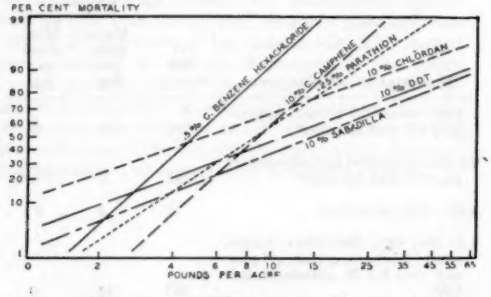

FIG. 1.—Dosage-mortality curves for the toxicity of the insecticides indicated above to adult harlequin bugs.

[1] Technical Contribution No. 1125, Texas Agricultural Experiment Station. Thanks are due the advanced students in the courses of toxicology and economic entomology for their assistance in collecting insects and making records.

Table 1.—The median lethal dose of insecticidal mixtures as indicated below for adult harlequin bugs.

TREATMENT	M.L.D. POUNDS PER ACRE
10% DDT-inert	12.2
10% Chlorinated camphene-inert	8.7
10% Chlordan-inert	5.1
10% Sabadilla-inert	14.9
.5% Gamma benzene hexachloride-inert	4.8
.25% Parathion-inert	8.6

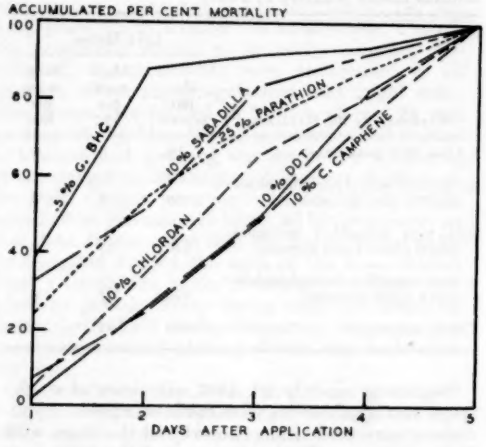

FIG. 2.—The accumulated percentage mortality on successive days as indicated following the application of the materials.

Checks or untreated bugs were included with each series of tests. The percentages of mortality were calculated by Abbott's formula.

The toxicity curves shown in figure 1 were calculated by the method described by Bliss (1938). These data show the comparative effect of the several materials when applied directly to the insects which were fed clean food during the observation period.

The MLD for each insecticidal dust is shown in table 1. Benzene hexachloride and parathion dusts were highly toxic to the harlequin bugs even at the low strengths of .5 per cent and .25 per cent, re-

spectively. Chlordan and chlorinated camphene were more toxic than DDT or sabadilla at 10 per cent concentration.

The rapidity of the action of each insecticide is indicated by the accumulated percentages of mortality shown in figure 2. Benzene hexachloride was the quickest-acting material, killing nearly 90 per cent of the population within 48 hours. Chlorinated camphene was the slowest acting poison. Twenty-five per cent of the individuals were killed with this material by the fifth day.

CAGE TESTS.—In the cage tests conducted during 1947 turnip plants were dusted and the harlequin bugs were released on the plants after the dust application had been made. In the tests conducted during 1948 both the bugs and cabbage plants were dusted. A metal chamber was placed over the plants on which approximately 35 insects had been released. A known dose of each insecticide was dusted into the chamber and allowed to settle for 30 seconds. The plant was then caged for daily observation. The cage was removed at the end of the 5-day period and the plants were carefully examined for dead and living bugs. Comparable check cages were included with each series of tests. The percentages of mortality were calculated by Abbott's formula as shown in table 2.

Table 2.—Mortality of adult harlequin bugs following dust application to turnip plants in 1947 and to both bugs and cabbage plants in 1948

TREATMENT	CONCENTRATION OF DUSTS, PER CENT	DOSAGE, POUNDS PER ACRE	NUMBER CAGES	NUMBER INSECTS	PER CENT MORTALITY[1]
Tests conducted in 1947					
DDT	10	16	3	76	100.0
	10	16	3	69	88.4
Benzene hexachloride	4.3[2]	16	3	72	88.9
	4.3[2]	16	3	73	84.9
Sabadilla	10	16	3	74	48.6
Chlorinated camphene	10	16	3	73	100.0
Tests conducted in 1948					
DDT	10	16	3	85	16.5
Chlorinated camphene	10	16	3	90	65.1
Chlordan	10	16	3	62	34.5
Sabadilla	25	11	3	97	23.7
Benzene hexachloride	3[2]	16	3	116	65.7
Parathion	1	16	3	102	80.1

[1] 5 days after application.
[2] Per cent gamma isomer.

It will be noted that good control was obtained from chlorinated camphene, DDT and benzene hexachloride in the 1947 tests. Effective control was obtained in 1948 from chlorinated camphene, parathion and benzene hexachloride, but DDT and chlorinated camphene dusts were not as effective as they were in tests conducted during 1947. The 1948 tests were made during a period in which the percentage relative humidity was low. These results indicate that the relative humidity may affect the toxicity of these materials.

FIELD TESTS.—A field of rutabaga turnips was used for this test. The dusts were applied with rotary hand guns early in the morning while the air was calm and dew was present. The number of adults and nymphs were recorded on about 400 linear feet of row before the dusts were applied and 5 days after the application. The percentages of reduction for each treatment are shown in table 3.

Table 3.—Control of harlequin bugs following dust application to rutabaga turnips in the field.

TREATMENT	RATE PER ACRE LBS.	PER CENT REDUCTION	
		Adults	Nymphs
10% DDT-inert	44	91.8	99.1
10% Chlorinated camphene-inert	36	96.7	98.4
20% Sabadilla-inert	46	80.6	98.8

These tests were made following a shower and dew formed each morning throughout the observation period. All the materials used were highly effective against nymphs. DDT and chlorinated camphene dusts were more effective against the adults than sabadilla.

SUMMARY.—Results of laboratory and cage tests indicate that chlorinated camphene, DDT, benzene hexachloride, and parathion are more effective against adult harlequin bugs than sabadilla or chlordan. Effective control may be obtained with sabadilla dust when used at a high concentration and dosage. Results of these tests indicate that the percentage relative humidity may affect the toxicity of DDT and chlorinated camphene.—6-8-48.

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Species of Ticks Associated with Rocky Mountain Spotted Fever Cases in Florida[1]

DOYLE J. TAYLOR[2], J. A. MULRENNAN[3], and D. C. THURMAN, Jr.[4]

Two cases of Rocky Mountain spotted fever appeared in the morbidity reports to the Florida State Board of Health in 1947.[5] One case occurred in Quincy, Gadsden County, and the other, with a fatal outcome, occurred in Fairvilla at the northern edge of the city of Orlando, Orange County. Surveys were made in these localities in an attempt to ascertain the tick species which might have been presumptively responsible for the transmission of the pathogenic organism.[6]

In addition to the foregoing, the environment of two other persons with febrile illnesses suspected of being spotted fever was also investigated in the hope of locating a possible arthropod vector. The first of these suspected cases occurred at Lake Wales, Polk County, and the second at a farm home in Manatee County, southeast of Bradenton.

[1] A contribution of the Communicable Disease Center Activities of U. S. Public Health Service and the Florida State Board of Health, Jacksonville, Florida.
[2] Entomologist, U. S. Public Health Service.
[3] Director, Division of Entomology and C.D.C. Activities.
[4] S. A. Sanitarian (R) U. S. Public Health Service.
[5] Records of the Bureau of Preventable Diseases. All information with regard to diagnosis of these cases of spotted fever was obtained from Dr. Edwin G. Riley, Epidemiologist, now County Health Officer, Polk County, Florida.
[6] Acknowledgement is made of the assistance of Entomological Inspector Carlis J. McLeod in making collections of ticks at Quincy.

The case of fever at Quincy, diagnosed as spotted fever from clinical symptoms and later verified by the complement fixation test, was reported to the State Board of Health as having an onset on April 13, 1947. The patient, a six year old girl who had not been away from the neighborhood for 6 months, had, according to her mother, been bitten by an unknown species of tick.

Collections of ticks were made from the family dog, a neighbor's dog, and with a cloth drag in the yard of the patient's home and nearby woods. The following species were found: *Amblyomma americanum* (Linn), the lone-star tick, and *Dermacentor variabilis* (Say), the American dog tick. Both of these species are possible vectors of the spotted fever according to Maver (1911), Parker *et al.*, (1943), and Hassler & Robinson (1946).

The Orlando patient was a six and one-half year old girl. The first symptoms appeared on September 12, 1947. A physician was called in on September 17; he transferred the patient to a hospital on September 19, 1947, and death occurred on October 9, 1947. Laboratory tests were made, the results of which supported the clinical diagnosis of spotted fever.

According to a statement by the mother of the patient, the child was in the habit of picking ticks from the family dog and dropping them into her lap until the task was finished, thus allowing sufficient time for the ticks to escape and crawl onto her body and bite. None of these ticks were preserved.

Collections of ticks were made from the family dog, and with a cloth drag from vegetation in the yard and pasture to the rear of the house. The collections include larvae of *Amblyomma* spp., larvae and one male adult of *Amblyomma maculatum* Koch, one larva of *Naemaphysalis leporis-palustris* (Packard), one male and two females of *D. variabilis* (Say); and three females of *Ixodes* spp. Several specimens from the tick collections were tested for spotted fever by the U. S. Public Health Service Virus Laboratory in Montgomery, Alabama, with negative results.

The first of the two suspected cases, both of which were diagnosed by clinical symptoms as spotted fever, occurred in Lake Wales, Polk County, and involved a sixteen year old boy. The fever in this case developed on April 25, 1947, and a rash appeared April 28th. This case was serologically negative for spotted fever and typhus.

In tracing the infection, it was learned that the patient had attended a boy scout camp on April 11th and 12th, 1947, near Davenport, Polk County, Florida. The patient stated that he received three bites, presumably from insects, while on this camping trip, but did not observe the arthropod responsible. This location was considered the most probable source of infection after all other points of origin were checked.

Collections of ticks were made from dogs and pigs in the vicinity of the Davenport Scout Camp. Only *Dermacenter variabilis* was obtained from both hosts.

The other suspected case occurred in Manatee County, in a four year old boy, who developed a fever on July 17, 1947, was taken to a hospital two days later, and was released July 25, 1947, after recovery. No laboratory blood tests were made.

No definite history of a tick bite was obtained; although ticks were present in the immediate vicinity of the home as evidenced by collections made from the family dog, a neighbor's dog and cat, and with a cloth drag in an adjacent cow pasture. *Dermacentor variabilis* was collected at this location as well as *Amblyomma maculatum*, *Rhipicephalus sanguineus* Latr. and *Ixodes scapularis* Say. Samples of these collections were submitted to the Montgomery, Alabama, U. S. Public Health Service Laboratory for testing for the presence of spotted fever organisms but the results were negative.

DISCUSSION.—In the course of the investigation of the four cases of fever reported, only one species of tick, *Dermacentor variabilis* was found to occur in all four localities. One other species, *Amblyomma maculatum*, occurred in two counties, Orange and Manatee. In Quincy, where one of the laboratory diagnosed cases occurred, the lone-star tick, *A. americanum* also was taken. The results of these collections from the vicinity of spotted fever cases are compatible with the records of Rumreich, *et al.* (1931), who found that in the focal areas, 5 to 20 miles in diameter surrounding case sites, the predominating species collected was *V. variabilis*. Occasional specimens of *A. maculatum* and *A. americanum* were taken. All of the present collections were made within a range of not more than one-half mile from the probable source of infection, which circumstantially incriminates the species of ticks collected.

As reported by Maver (1911), *Dermacentor variabilis* can transmit the western type of Rocky Mountain spotted fever experimentally, and as further reported by Dyer *et al.* (1931), may also be the responsible vector of the Eastern type of spotted fever. The present collections would therefore support the view that the American dog tick was the agent responsible for the transmission of spotted fever in the cases discussed here, despite the negative results secured from inoculation of some specimens into susceptible laboratory test animals.

Another possibility in the Orlando locality, is the presence of *Naemaphysalis leporis-palustris* in the collections from this place. According to Spencer (1931) the rabbit tick, although not infesting man, will transmit Rocky Mountain spotted fever from one animal host to another, thereby spreading the disease within its animal reservoir. On two occasions, mourning doves and bob-white quail were observed feeding in locations where the Orlando collections were made. According to Bishopp & Trembly (1945), ground inhabiting birds such as these may become heavily infested with the larval and nymphal stages of the rabbit tick. Early stages of other tick species are often found on these birds, thereby making possible the transmission of spotted fever organisms to tick species infesting a wider variety of hosts.

Haemaphysalis leporis-palustris was suspected of maintaining the rickettsia of spotted fever in nature as far back as 1925, even in the absence of the known spotted fever tick, *Dermacentor venustus* Banks. Parker & Spencer (1926) state, "It (the rabbit tick) does not bite man and hence, in an area where this tick is the sole transmitting agent, the virus of Rocky Mountain spotted fever could be present for years without evidence of its existence." The rabbit tick has widespread distribution in Florida and becomes of such economic importance with the proven occurrence of spotted fever in the State.

In Orlando the majority of the material collected with the drag cloth was identified as larval *Amblyomma maculatum*. Whether this tick had any connection with the transmission of the case was not determined. Part of this larval collection was among the material tested for spotted fever organisms in the laboratory at Montgomery, Alabama.

Recent work by Parker *et al.* (1943) and Hassler *et al.* (1946), incriminate the lone-star tick *Amblyomma americanum* as a vector of spotted fever. In Florida this tick is quite common and infests a wide variety of hosts, including man. This species, then, also enters the list of important suspected vectors of spotted fever cases in Florida.

SUMMARY.—Two cases of Rocky Mountain spotted fever, one of which was fatal, were reported in the 1947 morbidity reports of the Florida State Board of Health. Investigations of these two cases, and of two suspected cases, are discussed. Collections of ticks were made in the immediate locality of each case. The collections from the localities adjacent to the two reported cases of spotted fever yielded specimens of *Dermacentor variabilis*, *Amblyomma americanum*. *A. maculatum*, *Haemaphysalis leporispalustris*, and other undetermined species of *Amblyomma* and *Ixodes*. Collections from the vicinity of the two cases diagnosed by clinical symptoms only included specimens of *D. variabilis*, *A. maculatum*, *Rhipicephalus sanguineus*, *I. scapularis* and other undetermined species of *Ixodes*. Selected specimens from one of the definitely diagnosed case localities, and from one of the suspected case localities were checked for presence of spotted fever organisms with negative results.

CONCLUSIONS.—On the basis of circumstancial evidence presented, *Dermacentor variabilis* appears to be the most likely vector of spotted fever in Florida. The occurrence of *Amblyomma americanum* at the scene of one of these cases is not to be overlooked in view of recent discoveries.

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Comparison of Diluents in Insecticide Mixtures for Cotton Insect Control[1]

J. C. GAINES and R. L. HANNA, *Texas Agricultural Experiment Station, College Station*

Tests conducted by this station indicate that certain organic insecticides diluted with such materials as clay, talc or pyrophyllite will not prevent an increase of red spider mites on cotton. Increases in red spider populations have not been recorded on cotton treated with these insecticidal mixtures when they contained at least 40 per cent sulphur. Since the organic insecticides can be diluted with many different materials, it was deemed advisable to compare the toxicity of several insecticidal mixtures containing pyrophyllite and sulphur against the boll weevil, *Anthonomus grandis* Boh., and the bollworm, *Heliothis armigera* Hbn., and to determine the effect of these diluents on the red spider and cotton aphid, *Aphis gossypii* Glov., populations.

The tests reported were conducted in the Brazos river bottoms near College Station during 1947.

FIELD PLATS AND TREATMENTS.—A split plat latin square (4 by 4) arrangement was used for this experiment. The whole plats afforded excellent comparisons of the insecticides. The split plats afforded adjacent comparisons of the two diluents. Each of the 16 whole plats was 34 rows wide and of sufficient length to make one-fifth of an acre. Each whole plat was divided into two sub-plats, each 12 rows wide or one-tenth acre in size.

The four treatments were as follows: (1) 3 per cent gamma benzene hexachloride-5 per cent DDT containing either 40 per cent pyrophyllite or sulphur, (2) 20 per cent chlorinated camphene containing either 40 per cent pyrophyllite or sulphur, (3) calcium arsenate mixture containing either 33.3 per cent pyrophyllite or sulphur and (4) either pyrophyllite or sulphur alone. One sub-plat in each whole plat was selected at random to be dusted with the insecticide mixture containing pyrophyllite and the other sub-plat was dusted with the insecticide mixture containing sulphur. In the whole plat designated "check," one sub-plat was dusted with pyrophyllite and the other with sulphur.

Eight effective applications were made of each material. The first two applications, for early boll weevil control, were made on June 11 and June 23. The last six applications, for boll weevil and bollworm control, were made at 5-day intervals, from July 4 to July 29. In the last three applications the poundage was increased to control the bollworm adequately. An effort was made to make the actual weight of calcium arsenate in the calcium arsenate mixtures comparable to the weight of the other insecticides, but this was not achieved. The calcium arsenate was applied at the average rate of 9 pounds per acre as compared to 12 for the other treatments.

RECORDS.—The boll weevil infestation and the bollworm injury records were made at approximately 5-day intervals in the usual manner. The number of aphids and red spiders were recorded on 1 square inch of leaf surface on the fourth leaf from the top of the plant on 100 consecutive plants in each plat.

RESULTS.—The data were analyzed as shown in table 1. The seasonal averages for the different criteria are shown in table 2.

[1] Technical contribution No. 1117 Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

Table 1.—Analysis of data shown in table 2.

Source of Variation	Degrees of Freedom	Mean Square Pertaining to: Average Punctured Squares (Angles)	Average Bollworm Injury (Angles)	Aphids Per sq. Inch	Red Spiders Per sq. Inch	Yield, Pounds Seed Cotton
Whole plats						
Rows	3	165.08**	25.37	26.47	5.94	63.59
Columns	3	31.14	16.47	50.71	2.05	33.38
Treatments	3	162.03**	413.48**	695.92**	3.36	470.87*
Error (A)	6	9.39	5.02	44.41	1.90	57.56
Sub-plats						
Pyrophyllite vs. sulphur	1	.53	3.43	96.12	39.52*	12.75
Treats vs. Diluents	3	3.24	4.82	50.95	32.28	8.34
Error (B)	12	4.15	83.91	23.20	1.86	6.08
Total	31	39.39	48.86	100.42	3.78	69.67

* Significant.
** Highly significant.

The benzene hexachloride-DDT mixture, chlorinated camphene mixtures and the calcium arsenate mixtures were equally effective against the boll weevil and gave significantly better control than the diluents alone. Pyrophyllite or sulphur did not affect the toxicity of these insecticides when used against the boll weevil.

Against the bollworm, all three treatments gave significantly better control than the diluents alone and the benzene hexachloride-DDT mixture was significantly better than the calcium arsenate mixture. There was no significant difference between the benzene hexachloride-DDT mixture and chlorinated camphene, nor between chlorinated camphene and the calcium arsenate mixture. The different diluents had no effect on the toxicity of the three insecticides to the bollworm.

The aphid population was significantly higher in the calcium arsenate treated plats than it was in the plats treated with the other materials.

Red spider populations were about the same on the plats treated with organic insecticides mixed with pyrophyllite. The sulphur diluent, however, was significantly better than the pyrophyllite against this pest. The sulphur used in the insecticide mixtures prevented red spider increases.

The benzene hexachloride-DDT and the chlorinated camphene both gave significantly better yields than calcium arsenate. The use of different diluents did not affect the yields.

Table 2.—Average insect infestation and yields of seed cotton following treatments as indicated at College Station, Tex.

	Check		Benzene Hexachloride-DDT		Chlorinated Camphene		Calcium Arsenate	
	Pyrophyllite	Sulphur	Pyrophyllite	Sulphur	Pyrophyllite	Sulphur	Pyrophyllite	Sulphur
Average boll weevil infestation[1]								
Per cent of squares punctured	25.6	26.5	18.0	15.0	12.2	11.9	12.1	12.8
Equivalent angles	29.90	30.38	24.75	22.66	20.22	20.02	20.14	20.86
Difference	.48		−2.09		−.20		.72	
Average boll injury[2]								
Per cent of bolls injured	18.9	19.6	2.0	2.9	6.3	5.7	8.2	9.8
Equivalent angles	25.72	26.03	7.86	9.74	14.49	13.09	16.31	18.13
Difference	.31		1.88		−1.40		1.82	
Average number aphids								
Per square inch[3]	5.78	2.31	.04	.17	.33	.41	25.11	14.51
Difference	−3.47		.13		.08		−10.60	
Average number red spider								
Per square inch[4]	4.05	.26	2.49	.86	3.14	.49	1.06	.24
Difference	−3.79		−1.63		−2.65		−.82	
Pounds seed cotton								
Per plat	51.02	51.45	67.48	67.92	66.92	66.80	57.30	61.60
Per acre	1276	1286	1687	1698	1673	1670	1430	1540
Difference	10		11		−3		108	
Gain over check			411		390		204	

[1] Average of 9 records made June 19 to July 28.
[2] Average of 4 records made July 28 to August 11.
[3] Average of 2 records made July 30 and August 6.
[4] Average of 2 records made July 30 and August 6.

Collecting Parasites of White Grubs for Puerto Rico: Then and Now

GEORGE N. WOLCOTT,
Agricultural Experiment Station, University of Puerto Rico, Rio Piedras

By taking advantage of modern means of transportation, the entomologist engaged in parasite introduction may readily obtain results in amount and character that were formerly impossible. Instead of being confined to chosing an inactive stage of the parasite for shipment in cold-storage, the speed of airplane express service now makes possible the collection, transportation without refrigeration, and release of adults within such a short period of time that mortality is negligible. This is well illustrated by the change in methods of introduction of *Tiphia* wasps into Puerto Rico for the attempted natural control of white grubs present there.

Previous to the introduction of the giant Surinam toad, *Bufo marinus* (L.), into Puerto Rico in 1920 and 1923, and its establishment and rapid spread through all the coastal regions of the Island, the injuries caused by white grubs to all agricultural crops were by far the most serious and pressing of all entomological problems. The reappearance of white grub injury during the last few years reflects the first drop in abundance of toads since their first introduction, and has necessitated taking up the consideration of other natural means of white grub control: specially the introduction of *Tiphia* wasps.

"Because of the difficulty and comparative lack of success in controlling white grubs in Porto Rico by artificial and mechanical means, and the scarcity of any important native parasites and predators on them, one of the first acts of Mr. D. L. Van Dine, the first Entomologist of the Sugar Producers' Experiment Station at Rio Piedras, was to arrange for the importation of promising parasites of white grubs of other countries into Porto Rico. Mr. C. E. Hood was employed to collect and ship them, and as the natural enemies of white grubs in the United States had been most thoroughly studied in Illinois by Prof. S. A. Forbes, he made his headquarters in Professor Forbes' laboratory at the University of Illinois" (Wolcott 1922). After Mr. Hood's death, the writer was appointed to continue the work, and he collected *Tiphia* cocoons in Illinois for two years, from 1912 to 1914, during which time 2560 cocoons were sent to Puerto Rico.

Immediate shipments of the material, as soon as collected, resulted in discouragingly small and scattered emergence of adults, thus the total results of the later season's work were kept in cold-storage in Illinois, packed in an ice-cream tub, and expressed to New York in the spring, and brought to Puerto Rico with the ship's stores in cold-storage in charge of the Chief Steward. Delivery of the final sending was made at the port of Guánica, only a few miles from the point of release of the adults at Hda. Santa Rita. This not only sounds complicated; it was so in fact. It depended originally on finding the field where *Tiphia* cocoons were present in abundance just as it was being plowed, necessitating a constant patrol during plowing season, by train, by interurban and by foot, of the Champaign-Bloomington-Decatur triangle, to arrive at the presumably most desirable field at the proper time. Some of the cocoons thus collected were parasitized by the Rhipiphorid beetle, *Macrosiagon pectinatus* (F.), and others by the Bombyliid flies, *Exoprosopa fasciata* Macquart and *Anthrax fulvohirta* Wiedemann; but all were liable to attack by the fungus *Isaria*, until methods of prevention were learned. After all the hazards of transport were eliminated, half or more of the emerging adults were males.

Despite the fact that some cosmopolitan insects, such as house flies and horn flies, occur in both Puerto Rico and Illinois, the differences in host and environment for such specialized insects as *Tiphia* wasps doomed this introduction to failure, even after all the difficulties of collection had been solved.

As contrasted with the seriousness of the white grub problem in Puerto Rico, it always has been and still is of but minor importance in Cuba and Hispaniola, inspections of cane fields being plowed in these larger West Indian islands rarely showing any white grubs at all. To be sure, white grubs of numerous endemic species do exist, but the apparent cause of their scarcity was not obvious until the observed abundance of *Tiphia* wasps in the mountains of Haiti (Wolcott 1938) indicated one possibility. In 10 days last winter (November 26th to December 6th, 1946), of which the first four had been devoted to finding the specific localities where mass collections of adults could be made, the writer collected 148 adult females of *Tiphia hispaniolae* Wolcott, feeding on the nectar of the flowers of wild carrot, *Daucus carota* L., at Kenscoff, Haiti. These were sent by air-express from Port-au-Prince, Haiti to San Juan, Puerto Rico, in four shipments, and were received by Dr. Luis F. Martorell, who released the wasps at Rio Piedras and at Isabela. For the majority of the wasps, this was a period in captivity of less than 24 hours. The total mortality of all wasps, including those which had been held for a day or two before shipment, was only six per cent. The comparative ease and speed with which so many live and active females could be collected in Haiti, and released in good condition in Puerto Rico so soon afterwards, is in most striking contrast to the delays incident to the collection of cocoons in Illinois. After two years experience, the optimum total emergence from the cocoons from Illinois was 79 per cent, but from an earlier shipment only 44 per cent, and from some shipments, no live wasps were obtained.

Even if the existence of the Haitian *Tiphia* had been known, or even suspected 35 years ago, its importation into Puerto Rico at that time would have been virtually impossible. The only dependable transportation consisted of the Hamburgh-American Line SS "Präsident," which made the trip from St. Thomas to Puerto Rico, Hispaniola, Jamaica and southern Cuba, and return, every month. Although adults of *Tiphia hispaniolae* occur from sea-level to the highest mountains, they may be most readily collected from, and are most abundant on the flowers of wild carrot which grow at moderate elevations, accessible from Port-au-Prince until quite recently only by the roughest of trails. Indeed, it is the advance in means of transportation: from foot and mule-back to automobile, monthly steamer and to daily airplane, which has had the most effect in developing present methods of parasite introduction.

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Reducing Curly Top Infection with Insecticides

J. R. DOUGLASS, K. E. GIBSON, and H. C. HALLOCK, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Curly top is one of the most destructive of all virus diseases of beans, beets, and tomatoes in the affected areas of the western part of the United States. For years various workers have tried to prevent curly top by controlling its vector, the beet leafhopper, *Circulifer tenellus* (Baker). Romney (1943) showed that significant reductions in curly top and increases in the seed yields occurred when the seed-beet fields were sprayed in the fall with pyrethrum-in-oil for control of the beet leafhopper. Douglass *et al.* (1939) showed that pyrethrum was very effective in killing beet leafhoppers, but had no residual effect and consequently, owing to reinfestations, did not control curly top on beets grown during the summer for sugar. Recent experiments at the Twin Falls, Idaho, laboratory of the Bureau of Entomology and Plant Quarantine showed that DDT was effective in killing this leafhopper and had good residual effect.

The object of the test described in this note was to determine whether a planting of sugar beets of a variety highly susceptible to curly top could be protected from the disease by applications of DDT in heavy leafhopper infestations. A small field was rented in the King Hill area of Idaho, where the plantings are subject to as extreme a leafhopper exposure as is known in this state. On March 27, 1947, approximately 0.5 acre of R. and G. Old Type, a variety of beets not resistant to curly top, was planted in soil that proved to be low in fertility. The planting was timed so that the beets would be in the seedling stage, the period of greatest susceptibility, when the spring movement of the leafhopper was at its peak. The plants began to emerge about April 10, and all plants were above ground within a few days. This planting was dusted wih a 10 per cent DDT-pyrophyllite mixture as follows:

DATE	POUNDS PER ACRE	DATE	POUNDS PER ACRE
April 22	20	May 20	22
25	14	23	26
May 3	18	26	26
12	18	29	27
15	16	June 3	32
17	23	12	30

The total dosage of DDT was 27.2 pounds per acre.

On May 14 and 15 the plants were thinned to approximately 12-inch spacings. The beets made good growth during the rainy period until about the middle of June. The cooperator who irrigated the plots did such a poor job that many of the leaves wilted to the ground, burned, and died. Examination on July 26 showed 37 per cent of the plants with curly top disease. Very few plants died from curly top during the season. Counts of plants made on October 27 showed an average stand of 95 per cent. The plot was harvested on October 27 and yielded at the rate of 21.7 tons of beets per acre.

There were no untreated plantings of R. and G. Old Type beets in the area for use as a check on the treated planting. It is known from experience that this susceptible variety cannot be grown successfully under the leafhopper conditions that existed during 1947. There were 16 leafhoppers per plant at the peak of the spring movement into beet fields in the nearby Buhl-Castelford area. This was the highest infestation in the area for 10 years. About 31 per cent were carrying the virus of curly top. Commercial fields of beets in the area, however, were planted to varieties that are resistant to curly top except during the early stages of their growth, and they were infested with leafhoppers too late in the season for maximum infection. About 18 per cent were infected, and the average yield was about 17 tons per acre. Curly top damage was severe on susceptible crops. For example, 98 per cent of the tomato plants in limited commercial plantings in the vicinity of the test plot were killed by curly top.

FIG. 1.—R. and G. Old Type beets protected from curly top infection by controlling the beet leafhopper. Photographed August 7, 1947.

Evidently some of the treated plants were infected before the first dust application was made, as there were leafhoppers present in the field at this time. Considering the drastic exposure and the unfavorable season for insect control, the treatment gave good protection from infection. It is not practical, however, to make such a large number of applications, and accumulations of DDT in the soil from such applications over a period of time might be detrimental Unusually frequent rains were partly responsible for the large number of applications, as the dust was often washed off the day it was applied. However, this test was designed to protect the planting from infection under conditions of extreme exposure.

The results reported herein on the use of DDT to control curly top are too preliminary in nature to form any basis for recommendations.—4-18-48.

[1] This work was carried out in general cooperation with the Bureau of Plant Industry, Soils, and Agricultural Engineering of the U. S. Department of Agriculture, the Idaho Agricultural Experiment Station, and the State of Idaho Pest Control Commission. Thanks are due H. C. Manis, of the Idaho Agricultural Experiment Station, for reviewing this manuscript.

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Insecticide Tests for the Control of Coleopterous Larvae Attacking Peanuts in the Soil

T. N. DOBBINS, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine,* and W. D. FRONK, *Virginia Agricultural Experiment Station, Blackburg*

Grayson & Poos (1947) have shown that the southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber, is currently the principal insect pest injuring developing peanut pods throughout the commercial peanut-growing area in southeastern Virginia, although injury is also caused by other scarabaeid larvae, principally *Strigoderma arboricola* (F.), and by undetermined species of wireworms (Elateridae). In field trials these workers found that the number of pods injured by larvae of the southern corn rootworm was reduced 47 and 84 per cent by soil applications of 25 and 100 pounds of DDT and 52 per cent by three applications of a water suspension containing 0.66 per cent of DDT to the foliage of peanuts for the control of tobacco thrips, *Frankliniella fusca* (Hinds).

In tests at the Tidewater Field Station of the Virginia Agricultural Experiment Station at Holland Va., in 1947, two comparable series of square-rod plots were laid out in a field of peanuts, and identical treatments of DDT and benzene hexachloride dusts were applied to the soil for the control of larval injury. There were four replications of each treatment in each series. The first series of plots was treated on June 24 and the second on July 14. A total of 4 pounds of dust containing the desired strength of active ingredient was applied to each plot. The dusts were broadcast by hand as uniformly as feasible and worked into the upper 1 to 2 inches of the soil with a garden rake. Estimates of larval injury to pods were made on September 9. A minimum of 100 pods were examined in each plot. The results of these examinations are summarized in table 1.

Table 1.—Control of injury to peanut pods by coleopterous larvae following applications of DDT and benzene hexachloride dusts to the soil on the dates indicated. Holland, Va. 1947.

Insecticide	Pounds of Active Ingredient Per Acre	Per Cent of Peanut Pods Injured by—			
		Southern Corn Rootworm		Other Larvae[1]	
		June 24	July 14	June 24	July 14
Benzene hexachloride	0.5[2]	16.1	12.9	0.6	3.5
	1[2]	8.9	12.0	0.4	2.1
DDT	25	31.4	18.2	3.8	8.0
	50	22.2	23.1	2.9	7.8
	100	11.0	6.3	1.1	0.4
Untreated check		49.0	37.9	0.6	3.3
Difference required for significance at 5% level		15.3	15.7	[3]	[3]

[1] Principally *Strigoderma arboricola.*
[2] Gamma-isomer content.
[3] Not calculated because some of the plot-replicate values were zero.

Table 2.—Injury to peanut pods by coleopterous larvae following application of insecticidal sprays to the foliage of peanut plants for the control of tobacco thrips. Beltsville, Md., 1947.

Treatment	Number of Pods Examined	Per Cent of Pods Injured by—			
		Southern Corn Rootworm		Other Larvae	
		Mean	Range	Mean	Range
Emulsions:					
Benzene hexachloride, 0.1 per cent gamma isomer[1]	1587	6	4–8	4	1– 7
Chlordan, 0.1 per cent[2]	1507	17	10–29	5	3– 7
DDT, 4 per cent[3]	1689	14	7–25	6	2–11
Water sprays:					
Parathion, 0.05 per cent[4]	1876	26	13–48	8	5–11
Chlorinated camphene, 0.1 per cent[5]	1706	25	17–39	10	1–21
Untreated check	1765	29	13–49	10	8–11
Difference required for significance at:					
5 per cent level		9		4	
1 per cent level		12		6	

[1] Prepared from a commercial 10% emulsifiable concentrate.
[2] Diluted from stock solution of chlordan (tech., 10% by weight) in xylene plus 5 ml. of Igepal CA-Extra Conc. (condensation product of ethylene oxide and an alkylated cresol) per gallon of spray.
[3] DDT 151 grams, xylene 296 ml., Igepal CA-Extra Conc. 20 ml., water to make 1 gallon.
[4] Prepared from a 15% wettable powder.
[5] Prepared from a 25% wettable powder.

An attempt was made to measure any differences in yields of field-cured peanuts by harvesting eight plants from each plot in late September and weighing the nuts produced by each lot. No significant differences in yield were shown, although these data may not be dependable because of the small areas involved. However, it is evident that coleopterous larvae do decrease the quality and quantity of field-cured peanuts, and a measure of this damage would be desirable.

In other tests, at the Agricultural Research Center, Beltsville, Md., the foliage on small field plots of peanuts was treated with various insecticidal dusts and sprays for the control of tobacco thrips in 1947. Observations were later made to determine the effect of these applications on the injury to developing pods by coleopterous larvae. Each spray was applied four times, on June 12, 18 (followed immediately by heavy rain) 20, and 30, with a knapsack sprayer. An oil-burner atomizing nozzle was used for the 4 per cent DDT emulsion and conventional disk-type nozzles were used for the other sprays. The dusts were applied on the same dates with a rotary hand duster.

When yield data were recorded from the plots on September 29 and 30, marked differences in insect injury to pods from sprayed and check plots were evident. These differences appeared to be correlated with treatments. No consistent differences in pod injury between dusted and check plots were evident, however. The pods from three plants selected at random from each of the sprayed plots were therefore examined on October 3 to determine the percentages of pods showing insect injury. The results are recorded in table 2.

The 1947 growing season at Beltsville and Holland was characterized by abundant, well-distributed rainfall, which favored attack by the southern corn rootworm in the lower, less-well-drained areas. At Holland benzene hexachloride at 0.5 pound of gamma isomer per acre or DDT at 25 pounds per acre significantly reduced the amount of injury to pods, but the data suggest that practical control will require a minimum of 1 pound of the gamma isomer of benzene hexachloride or 100 pounds of DDT when these insecticides are applied to the soil. The higher dosages did not appear to injure the growth of peanuts. Both dosages markedly reduced the injury to the peanut foliage by the tobacco thrips. The taste of the peanuts was not affected by the benzene hexachloride. These experiments, however, must be regarded as preliminary.

At Beltsville a highly significant reduction in pod injury resulted from the foliage applications of the benzene hexachloride emulsion (0.1 per cent gamma isomer), and significant reductions in pod injury also resulted from the foliage applications of the emulsions containing 0.1 per cent of chlordan and 4 per cent of DDT. Poor coverage of the foliage was perhaps responsible for the negligible control obtained with the wettable-powder sprays containing 0.05 per cent of parathion and 0.1 per cent of chlorinated camphene. At Beltsville approximately half the pod injury caused by larvae other than the southern corn rootworm was attributed to wireworms, whereas at Holland this was due largely to *Strigoderma*.

Pending the results of more complete tests, the use of benzene hexachloride as a soil insecticide for the control of subterranean insects attacking commercial plantings of peanuts is not recommended, because of the possible adverse effects of this insecticide on the marketability of the peanuts or other crops grown subsequently in treated soils.

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Germination of Fumigated Peanuts

J. M. GRAYSON, *Virginia Agricultural Experiment Station, Blacksburg*

In the summer of 1945 the question arose as to the effects of fumigation with chloropicrin (CCl_3NO_2) upon the germination of peanut seed. Since there is apparently very little published information on the germination response of fumigated peanuts, the writer planned some tests to obtain at least preliminary data in answer to this problem. The resulting tests involved the use of chloropicrin[1] at concentrations equal to and above those employed in normal usage. Corn was included with peanuts at each exposure as a matter of comparison, and the tests were designed so as to determine the maximum concentration to which the seeds could be exposed without causing a reduction in germination. The tests were conducted at the Tidewater Field Station of the Virginia Agricultural Experiment Station, located at Holland.

The fumigation vaults were 10-gallon garbage cans that had a strip of rubber fitted to the top rim of each to insure a tight seal when the lid was forced on. In most of the tests each sample was composed of approximately 85 peanut seed and 100 corn seed. Temperature control within practical limits was attempted, and the temperatures actually obtained were determined from thermographic records of each exposure period. The moisture content of the seed was raised, when desired, by sprinkling it with water from 12 to 24 hours prior to fumigation.

Trial tests with chloropicrin revealed unshelled peanuts to be more resistant than shelled peanuts to reduction in germination, and indicated the moisture content of the seed to be a more important factor than either temperature or length of exposure period in determining the percentage germination following fumigation. Therefore, subsequent tests were designed to control temperature and exposure period but to vary the moisture content of the seed.

The moisture content[2] of peanuts in storage on farms in Tidewater, Virginia was found to vary from approximately 6 per cent to slightly higher than 12 per cent between early December and late April. In the same area the moisture content of corn was found to vary from 15.3 per cent up to as high as 22 per cent soon after harvesting but dropped to approximately 14.5 per cent during the winter and early spring months.

Six tests, each involving 6 different concentrations varying from 1 to 10 pounds per 1000 cu. ft., were made with chloropicrin. The results for shelled peanuts subjected to a 24-hour exposure period at an average temperature of approximately 72° F. were as follows: (1) at moisture contents below 10 per cent very little reduction in percentage germination occurred from rates up to 6 pounds, and reduction in germination was not serious from rates up to 10 pounds; (2) at moisture contents greater than 14 per cent slight reduction in germination resulted from a 2-pound rate and considerable reduction in germination occurred at higher rates. For the same

[1] Material used was *Larvacide* obtained from Innis, Speiden & Co.

[2] Determinations made by Prof. H. H. Hill, Chemist, Virginia Agricultural Experiment Station.

exposure period and average temperature the corn seed showed very little reduction in germination at rates up to 8 pounds when the moisture content remained below 14 per cent; however, the germination was affected at a 1-pound rate and seriously reduced at a 2-pound rate when the moisture content exceeded 19 per cent.

For fumigation purposes, chloropicrin is usually recommended at concentrations ranging from 1 to 3 pounds per 1000 cubic feet for a 24-hour exposure period. From these preliminary data it would appear that either shelled or unshelled peanuts could be fumigated with chloropicrin at recommended concentrations, under the conditions stated, without reduction in germination provided the moisture content does not exceed 10 per cent. Also, shelled peanuts would appear to be as resistant to germination injury from chloropicrin as the seeds of corn at comparable moisture contents of each.—7-12-48.

Aphid Control with Hexaethyl Tetraphosphate

D. G. DENNING
University of Wyoming, Laramie

During the latter part of August and early September, 1947, a number of willow trees in Laramie, Wyoming were severly infested with an aphid, *Pterocomma smithiae* (Monell).[1] When control with several insecticides failed it was decided to try hexaethyl tetraphosphate. To one hundred gallons of water in the spray tank one pint of the concentrate[2] was added; no wetting agent was used. A commercially operated high pressure sprayer was used to apply the spray at the rate of about ten gallons per tree, the trees being approximately thirty feet high. Spraying was done in the morning under cool partly cloudly conditions. Four and one-half hours later the trees were examined, and practically 100 per cent control of all aphids (winged and wingless) had been obtained. A large variety of other insects was found to have also been killed, these were collected and sent to the Division of Insect Identification, U. S. National Museum for determination. A list of the insects killed by this insecticide:

Anatis lecontei Csy.
Adalia bipunctata (L).
Hippodamia convergens Guér.
Brachylomia populi (Strecker)
Tendipes atrella Townes
Metasyrphus arcuatus (Fallén)
Scaeva pyrastri (L.)
Syritta pipiens (L.)
Chrysotoxum ypsilon Will.
Melanostoma obscurum (Say)
Eupeodes volucris O.S.
Villa lateralis (Say)
Psilocephala aldrichi Coq.
Chyromya flava (L.)
Dolichopus sp.
Hylemyia montana Mall. (?)
Hylemyia sp.
Hylemyia ciliciruru (Rond.)
Ophyra leucostoma (Wied.)
Musca domestica (L.)
Muscina stabulans (Fall.)
Sarcophaga l'herminieri (R.D.)
Phormia regina (Mg.)
Lissonota montana Townes
Cicadellidae (undetermined)

The next day only three living aphids could be found and the following day only one could be found.

The operator who applied the spray had both hands wet from the solution but no adverse effects were noted. At no time was any deleterious effect on the foliage or any other part of the tree observed.

[1] Now entomologist with the Wisconsin Alumni Research Foundation.
[2] In cooperation with the Wisconsin Agr. Expt. Station.

Tetraethyl Pyrophosphate, Parathion, and Benzene Hexachloride to Control the Pea Aphid

J. E. DUDLEY, JR., T. E. BRONSON, and P. V. STONE, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In field-plot experiments for control of the pea aphid (*Macrosiphum pisi* (Kltb.)) on canning peas in Wisconsin, insecticidal dust mixtures in different formulations are compared each season. Derris dusts containing about 0.75 per cent rotenone have been used as a standard of comparison. In 1947 tetraethyl pyrophosphate, parathion, and benzene hexachloride were included in these experiments. Results of tests with these materials in comparison with DDT and rotenone dusts are reported herein.

Talc was used as a diluent for all these mixtures except parathion. For this mixture a clay (aluminum magnesium silicate) was used. The tetraethyl pyrophosphate dust was prepared and applied the same day. The other dusts had been mixed several weeks previously. The DDT dust was prepared by dissolving technical DDT in a nonvolatile solvent consisting chiefly of di- and tri-methylnaphthalenes, and spraying the solution onto talc in a mixing machine.

All dusts were applied late in June at the rate of 35 pounds to the acre by means of a nozzle-type power duster equipped with a 45-foot cloth trailer. Each treatment was replicated six times on 0.2-acre plots of canning peas of the Perfection variety, the plots being randomized within blocks. The infestation was determined with the aid of a net.

Table 1.—Comparative effectiveness of five dusts against the pea aphid.

TREATMENT	LIVE APHIDS PER 5 SWEEPS AFTER 1, 2, AND 3 DAYS	REDUCTION IN INFESTATION
Tetraethyl pyrophosphate 2.5%	13	96%
Parathion 0.5%	29	92
DDT (technical) 1.25%, nonvolatile solvent[1] 2.3%	36	90
Derris (0.6% rotenone), paraffin-base oil 2%	55	85
Benzene hexachloride technical (0.85% gamma isomer)	125	65
Difference required for significance at odds of 19:1	42	—

[1] A proprietary mixture consisting chiefly of di- and trimethylnaphthalenes.

The results given in table 1 show that there was no significant difference between tetraethyl pyrophosphate, parathion, DDT, and derris, but all these insecticides were superior to benzene hexachloride at the strengths tested. The maximum benefit derived from derris and DDT could not be determined in the 3-day period of observation.

Nutritional Value of Phosphatic Insecticides

D. O. WOLFENBARGER

One of the characteristics of a good insecticide is that it shall not injure the host plant while it reduces or eliminates the insect infestation. An insecticide which would control insect infestation and, at the same time would possess nutritive value for the plant would be of scientific interest as well as have practical significance.

Yields of potatoes are greatly increased through the use of DDT where the potato leafhopper, *Empoasca fabae* (Harr.), is abundant. It was pointed out by Wolfenbarger & Heuberger (1946)[2] that mass action of different potato leafhopper populations was involved in this increase. One leafhopper per 100 plants, for example, is, by this principle, more important than is one leafhopper in a population of 10, 100, or 1000. The pre-DDT insecticides were not sufficiently potent to show this effect under field conditions.

The newer phosphatic insecticides appear to have provided increases in yield that may be explained by something other than mass actions of insect populations. This group includes tetraethyl pyrophosphate, and parathion. Data in the reports by Campbell & Pepper (1948)[1] on parathion combined with bordeaux 8-8-100, and by Wolfenbarger (1947)[3] on hexaethyl tetraphosphate combined with disodium ethylene bisdithiocarbamate and zinc sulphate, suggest yield increases out of proportion to the insect control obtained. Neither author, however, remarked or gave an explanation for it. Observations and data taken over a 2-year period are now considered evidence for interpreting part of the yield increases as due to nutritional effects.

METHODS AND MATERIALS.—The observations and data reported herein were taken from regular potato field plot experiments conducted on Perrine marl soils of southern Florida. A standard 4-row power sprayer was used to apply the spray materials for all treatments. A fungicide, two quarts of disodium ethylene bisdithiocarbamate,[4] plus a pound of zinc sulphate, per 100 gallons of water, was used for spraying for control of ths severe late blight disease epidemics. It was used to protect plants in all treatments, and it constituted the check treatment. The phosphatic materials were combined with the disodium compound mixed in the spray tank. One-half pound of hydrated lime per 100 gallons of water was used in the 1947 experiments but was found unnecessary, and was omitted in the 1948 experiments.

Fourteen treatments were used in the 1947 insecticide-fungicide test, three of which constituted a dosage concentration series using a commercially available phosphatic insecticide.[5] Fourteen treatments were also used in the 1948 test, one of which was the commercially available insecticide, another which was reported to be 95 per cent tetraethyl pyrophosphate, and another phosphatic material which was 25 per cent wettable parathion. For purposes of this paper the data from plants treated with the phosphatic materials were excerpted.

The contents of the phosphatic insecticide[1] used in 1947 were listed as hexaethyl tetraphosphate 50 per cent and inert ingredients 50 per cent. The contents of the material used in 1948 were listed as tetraethyl pyrophosphate 9 per cent, other organic phosphates 14 per cent, and inert ingredients 75 per cent.

The serpentine leaf miner, *Liriomyza pusilla* (Meig.), was the most serious insect pest of both the 1947 and the 1948 seasons. The green peach aphid, *Myzus persicae* (Sulz.), became abundant in both seasons. Other insect attacks are considered to have been so slight as to be of no significance in either year. The potato leafhopper, *Empoasca fabae* (Harr.), although injurious to beans in south Florida has not attacked the potato.

The treatments in the experiments in both seasons were replicated four times by the randomized block method. The plots were 4 rows wide, (12 feet), by 50 feet long. All data were taken from the two inside rows of each plot. The first spray was applied when the plants were about 4 to 10 days old. Sprays were applied at intervals of from 5 to 15 days afterward. From three to five nozzles per row were used to thoroughly cover the plants.

RESULTS.—*The 1947 experiment.*—Six applications of spray were applied to these plants, totaling approximately 1100 gallons per acre for the season. Leaf miner and aphid counts were made twice during the season. A summarization of the results, insect control in per cent, and yield as bushels per acre is presented in table 1.

Table 1.—Results of 1947 experiment.

	Phosphatic Insecticide Pts. per 100 Gals. 2	1	½	Fungicide Spray 0 (Check)
Per cent control of leaf mines	35	19	3	—
Percentage control of aphids	65	64	25	—
Yield, bu. per A.	282	281	238	249

Leaf miner control was slight with this insecticide, even when twice the suggested amount was used (1 quart per 100 gallons). Aphid control was fair with dosages of 2 pints and 1 pint per 100 gallons. The yields from the plants treated with the highest dosages, 2 pints and 1 pint, were the only insecticidal combinations with statistically significant increases over the check treatment.

The 1948 Experiments.—Eleven fungicidal applications, 9 of which contained the phosphatic materials, were made during the 1948 season. Approximately 1000 gallons of the phosphatic materials were applied per acre during the season. Two counts of the leaf mines and aphids were made during the season. A summarization of the results, insect control in percentage, and yields as bushels per acre is presented in table 2.

Parathion controlled the insects more efficiently than did the other phosphatic materials. Both the phosphatic insecticide and tetraethyl pyrophosphate data gave some control of the aphid. The yield data among the phosphatic materials were very similar, and were approximately 50 bushels per acre more than the check.

It is of interest to note (1) that the one pint

[1] Campbell, John C. and Bailey B. Pepper. 1948. Promising New Chemicals for the Control of Diseases and Insects. Amer. Potato Jour. 25: 82–86.

[2] Wolfenbarger, D. O., and J. W. Heuberger. 1946. Potato Yields from Different Potato Leafhopper Densities. Amer. Potato Jour. 23: 389–95.

[3] Wolfenbarger, D. O. 1947. The Serpentine Leaf Miner and its Control. Fla. Agr. Expt. Sta. Press Bul. 639: 1–6.

[4] *Dithane d-14*, secured from Rohm & Haas Company, used for all fungicide applications.

[5] *Vapotone*, secured from California Spray-Chemical Corporation; the phosphatic insecticides used in the tests reported.

Table 2.—Results of 1948 experiment.

	Insecticide			
	Parathion	Phosphatic Insecticide	Tetraethyl pyrophosphate	
	Amount Used per 100 Gallons			Fungicide Only
	2 lbs.	1 pt.	½ pt.	
Percentage control of leaf mines	93	19	39	—
Percentage control of aphids	88	69	63	—
Yields, Bu./A.	303	293	305	246

dosage of the phosphatic insecticide gave 19 per cent control of the leaf mines in 1947 and again in 1948; (2) that it gave 64 per cent control of the aphids in 1947 and 69 per cent in 1948; and (3) that the yield increase was 13 per cent over the check in 1947, and 19 per cent more in 1948. It is considered that these similarities have valuable implications, and that the minor differences may be attributed to chance occurrence.

An experiment termed "the nutritional test" was conducted combining 75 per cent phosphoric acid with DDT and fungicide in one treatment for comparison with other treatments. Approximately 1000 gallons per acre were applied during the 9 phosphatic applications, although 11 applications of the fungicide were applied. DDT was used in each insecticidal application, 2 pounds of 50 per cent wettable per 100 gallons, alone and combined with the phosphatic materials. Two leaf mine and aphid counts were made for this experiment. The data are summarized as percentage control of leaf mines and aphids, and of yields in table 3.

Table 3.—Results of the "Nutritional Test."

	Treatment Materials			
	DDT	DDT and phosphoric Acid	DDT and phosphatic Insecticide	
	Amount Used per 100 Gallons			Check (Fungicide Only)
	2 lbs.	2 lbs.-1 pt.	2 lbs.-1 pt.	
Per cent control of leaf mines	0	0	0	—
Per cent control of aphids	86	82	96	—
Yields, Bu./A.	217	250	230	198

The differences in leaf mines varied so little, both above and below the check, that zeros are given for percentages of control obtained. No insect control was expected from the phosphoric acid combination; none was obtained. DDT alone gave good aphid control, and was augmented but little by the addition of the phosphatic insecticide. Differences were observed in the rate of decline of the plants. The check plants declined first, followed by plants treated with DDT. Plants treated with the phosphatic materials remained greener longer. The yield data indicate something of the length of time the plants remained green. Unfortunately the yield data fell a bit short of statistical significance. Wet weather at planting time and seed piece decay produced such widespread differences between replicates as to result in lack of significance.

These observations have suggested that the phosphatic materials tested, most of them insecticides, functioned nutritionally on the potato plants. Since certain inorganic minor elements, copper, zinc, and manganese for example, are known to be taken up by leaves, it seems not impossible that the inorganic phosphate radical might be utilized in like manner.

Combinations of the phosphatic materials with the fungicide appeared to have made no change by reduction nor aid in control of late blight disease. The "hard" water used in the sprays may have reduced the effectiveness of the insecticides since they are considered to undergo more rapid decomposition by alkalinity.

Little is known concerning the phosphatic insecticides. Considerable fear has been expressed as to their toxicity to man. Caution is necessary, therefore, in their use and application until more is known of them and of their decomposition products.

SUMMARY.—Increases in potato yields were observed from plants treated with phosphatic insecticides in 1947 and 1948. Yields were increased with increases in dosage in 1947. Yields were increased with three different phosphatic insecticide materials and with phosphoric acid in tests in 1948. Insect control was obtained by the insecticide combinations but it appears not to account for all of the increases in yields. It is suggested that the yields were in response to nutritional ingredients of the phosphatic materials applied to the plants.—7-14-48.

A Tip-Infesting Sawfly on Rose

PAUL M. EIDE,[1] *U.S.D.A., Agr. Res. Adm. Bureau of Entomology and Plant Quarantine*

In May, 1940, the attention of the staff of the Sumner, Washington, laboratory of the Bureau of Entomology and Plant Quarantine was called to insect damage of the growing tips of Manetti rose plants in the Puyallup Valley. Examination revealed small sawfly larvae in the stems. Reared adults were identified by R. B. Benson, of the British Museum, as *Ardis sulcata* Cameron. At that time the insects did not appear to be numerous, nor did there seem to be a great deal of damage. Observations the next spring, 1941, in commercial plantings of Manetti roses revealed many similarly damaged tips. The insect was also found generally on wild roses in the Puyallup Valley.

This insect was originally described (Cameron 1882) from specimens from Germany and England. Servadei (1933) states that it has been reported also in Spain, France, Germany, Hungary, and England. It has not been reported previously in the United States.

The larval feeding habits of this insect are not those usually associated with sawflies. The eggs are laid while the leaflets are still in the bud, and they hatch soon after the first leaves unfold. The newly hatched larva crawls down the petiole and feeds on the small tender leaves still folded in the bud. When it has consumed these leaves, it bores into the end of the stem a short distance, an inch or less, and there it remains the rest of the larval period (Fig. 1). As the larva consumes little of the plant tissue for the size it attains, plant sap may be a large part of its food. After about a month the larva makes a small hole through the bark at the bottom of its burrow, through which it escapes and drops to the ground. From 1 to 3 inches below the surface it forms a small earthen cell, in which it remains until the next spring. The principal larval characters are retained until a short time before adult emergence, when it molts for

[1] Resigned April 4, 1945.

FIG. 1.—Terminal of Manetti rose shoot with bark cut away to expose sawfly larva in burrow.

FIG. 2.—Excessive branching of Manetti rose resulting from injury to growing tip by sawfly larva (right), compared with normal growth (left).

the last time and forms a true pupa. The adult breaks through the end of the cell and works its way up through the soil.

From a number of mature larvae kept under observation at the laboratory complete developmental records were obtained for five individuals. Three of these larvae, which were kept in a cool room, remained in the soil 268, 296, and 301 days. Two others, which were kept outside but not subjected to rain, required 286 and 288 days from larval entrance into the soil to adult emergence.

The eggs are rather large for the size of the insect, being about 1 mm. long and half that in diameter. They are inserted between the two epidermal layers of a leaflet near the midvein while the leaflet is still in the bud, and hatch after it unfolds. Considerable leaf area, sometimes an entire leaflet, is killed by the placement of the egg. One egg is usually laid in a bud, but as many as four eggs have been found. Three small larvae have been found in a single tip, but never more than one reaches maturity in one tip. It apparently takes the eggs about a week to hatch.

Full-grown larvae are 8 to 10 mm. long. In the first instar the larva is a glistening white, but in the last instar the body color is pale cream or ivory. The head is dark in all stages, and there is a dark area on the dorsal side of the last segment.

The pupal cell is constructed by cementing together particles of soil with some secretion produced by the larva. It is 5 to 8 mm. long and 2 to 3 mm. in diameter, and resembles the pupal cell of the rose sawfly, *Caliroa aethiops* (F.), except that it is longer, not so large in diameter, and concave on the anterior end.

The adults are small black sawflies 4 to 5 mm. long with a wing expanse of 8 to 12 mm. In size and color they are similar to the rose sawfly, but the two species can easily be distinguished by differences in wing venation. Adults were first seen in the field on March 28, 1942, and unhatched eggs were found as late as June 16.

Normally a Manetti rose shoot elongates through growth at the terminal. The destruction of this growing point by the sawfly larva causes several axillary buds along the stem below the tip to begin growing, and the result at the end of the season is a short main stem with several branches (Fig. 2). The normal shoot is an elongate, whip-like single stem, usually over 3 feet long. This long stem attains the desired diameter for propagation purposes, because it grows undisturbed throughout the season, and may furnish six to eight satisfactory cuttings. On injured growth the only portion usually large enough for propagation is the main stem below the branches, and seldom can more than two cuttings be obtained. The branches developing after the insect injury seldom attain the desired diameter because of their late start.

Manetti growers have customarily maintained blocks of mother plants, which are left in the ground year after year. This enabled the roguing out of unsatisfactory plants, particularly those affected with mosaic or virus diseases. In 1942 most of the Puyallup Valley producers pulled out their blocks of mother plants because of the excessive branching. In one field, which was not discarded, 92 per cent of the tips were infested. In lieu of mother plants dependence has been placed on the one-year plants for propagating material. The one-year plants are not usually damaged, because the terminal buds are not large enough to be attractive for egg deposition when the adults are abundant.

Damage to ornamental roses seems to be rare. Only three cases have been noted in which the larvae bored into flower buds. Attack on other varieties of roses grown for root stocks has not been observed, even when grown adjacent to Manetti that is heavily infested.

There seems to be only one generation of this sawfly a year, but the adults emerge and lay eggs on every warm day beginning about April 1 and continuing well into June. This long egg-laying period and the fact that the eggs and larvae are well protected except for a short time after hatching make chemical control difficult. Cultural control is also a problem, because the insect breeds in wild roses.

A small metallic green chalcid, *Habrocytus* sp. (determination by A. B. Gahan), was abundant in 1941, when it killed 30 per cent of the larvae in Manetti rose plants in the Puyallup Valley. Single specimens of *Epiurus euurae* (Ashm.) and *Lathrolestes* sp. (determinations by R. A. Cushman) were also reared from larvae.

Damaged tips, adults, or larvae have been observed on wild roses in Skagit, Island, San Juan, King, Pierce, Cowlitz, and Whitman Counties in Washington, and in Multnomah and Washington Counties in Oregon. Damage to commercially grown Manetti rose has been observed only in King and Pierce Counties.—5-28-48.

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Insect Food of the Vesper Sparrow

G. F. KNOWLTON and W. P. NYE,[1] *Utah Agricultura Experiment Station, Logan*

An examination has been made of 116 stomachs of the western vesper sparrow, *Pooecetes gramineus confinis* Baird. The birds were collected throughout Utah during the seasons of 1934 to 1945, inclusive.

Among the injurious insects eaten were:

One hundred two grasshoppers, 10 Mormon crickets, several lygus bugs, 74 false chinch bugs, 16 pentatomids, 268 leafhoppers of which 251 were *Eutettix tenellus* (Baker), 87 aphids including 64 *Macrosiphum pisi* (Kalt.), 4 click beetles, 24 scarabaeids, 48 leaf beetles including injurious flea beetles, a pea weevil, 48 alfalfa weevils and alfalfa weevil larvae, 2 clover leaf weevils, 80 lepidopterous caterpillars, 1 mosquito, 2 horseflies and 188 ants. The insects recognized were predominantly injurious, although a few beneficial forms were present, such as ladybird beetles, ground beetles, chrysopids, damsel bugs, big-eyed bugs and wild bees.

Recognizable insect food of the sparrow consisted of the following:

Thysanura 1
Orthoptera 111[2]
  Locustidae 102 (50 nymphs)[2]—*Camnula pellucida* (Scudder), 1, *Melanoplus packardi* Scudder 1, and *M. mexicanus* Riley 1.
  Tettigoniidae 10
    Anabrus simplex Hald. (10 nymphs)
Neuroptera 3
  Chrysopidae—*Chrysopa* sp. 3
Odonata 3
  Zygoptera 2
  Anisoptera 1
Hemiptera 185 (20 nymphs)
  Corixidae 1
  Miridae 18 (8 nymphs)—*Lygus elisus* Van D. 3, *L. hesperus* Knight 1
  Nabidae 2—*Nabis ferus* (L.) 1
  Lygaeidae 89—*Nysius ericae* (Schilling) 78 (4 nymphs), *Geocoris decoratus* Uhler 1
  Coreidae 8
  Pentatomidae 10—*Brochymena* 2; (also 6 eggs)
  Scutelleridae 2—*Eurygaster alternatus* (Say) 1
Homoptera 373 (60 nymphs)
  Cercopidae 3—*Clastoptera brunnea* Ball 1
  Membracidae 7—*Campylenchia latipes* (Say) (1 nymph)
  Cicadellidae 268 (59 nymphs)—*Eutettix tenellus* (Baker) 251 (55 nymphs), *Aceratagallia* 3
  Fulgoridae 1—*Scolops pallidus* Uhler
  Chermidae 3
  Aphididae 87—*Drepanaphis* sp. 1, *Macrosiphum pisi* (Kalt.) 64, *M. coweni* Hunter 1, *M. granarium* (Kby.) 1
Coleoptera 350 (32 larvae)
  Cicindelidae 1
  Carabidae 17 (1 larva)
  Staphylinidae 1
  Melyridae 1
  Meloidae 2—*Epicauta oregona* Horn 1
  Elateridae 4
  Dermestidae 1
  Coccinellidae 2—*Hippodamia convergens* Guerin 1
  Tenebrionidae 1
  Scarabaeidae 24—*Aphodius distinctus* (Mull.) 12
  Chrysomelidae 48—*Monoxia debilis* Lec. 3, *Systena bitaeneatus* Lec. 1, *Pachybrachis* sp. 1
  Bruchidae—*Bruchus pisorum* (L.) 1
  Curculionidae 67—*Phytonomus posticus* (Gyll.) 48 (29 larvae), *Hypera punctata* (Fabr.) 2, *Sitona hispidulus* (Fabr.) 3, *Thricolepis inornata* Horn 1
  Scolytidae 7—*Ips* sp. 1
Trichoptera 1
Lepidoptera 84 (80 larvae)
  Pyralididae 3—*Loxostege sticticalis* (L.)
  Sphingidae 1 (larva)
  Noctuidae 31 (larvae)—*Agrotis* 2
Diptera 40—(7 larvae and 3 pupae)
  Chironomidae 2
  Culicidae 1
  Bibionidae 2
  Tabanidae 2 (1 larva)
  Dolichopodidae 1
  Syrphidae 1
  Ephydridae 1
Hymenoptera 221
  Braconidae 1
  Formicidae 188—Many *Pogonomyrmex* sp. and *Formica* sp.
  Andrenidae 2
Miscellaneous insect eggs 3
Spiders 9
Solpugida 2
Pseudoscorpion 1
3158 plant seeds plus numerous seed and plant fragments.—5-4-48.

[1] Research professor and former graduate research assistant: respectively.

Biology and Control of a *Lecanium* Attacking Cultivated Blueberries

F. R. SHAW, J. S. BAILEY and A. I. BOURNE,
University of Massachusetts, Amherst

During the last 2 or 3 seasons a considerable outbreak of a species of Lecanium developed in the College plantings of cultivated blueberries. The identity of the scale is not as yet definitely known but it has tentatively been placed by authorities as *Lecanium quercifex Fitch*. This scale has been reported as a pest of oaks in Canada, New York and Massachusetts.

When a study of the outbreak was begun in the early spring of 1947 it was discovered that considerable winter mortality had occurred so that counts were made of both dead and living scales on infested bushes.

Counts from 10 twigs showing typical infestation revealed 93 living and 323 dead; a 77.6 per cent mortality. From these and subsequent records it was determined that the amount of winter mortality averaged very close to 75 per cent.

Before the spraying season opened, preliminary tests were made in the laboratory to indicate the relative value of different types of dormant sprays.

Infested cuttings were brought to the laboratory and thoroughly sprayed with a commercial dormant oil spray, a 25 per cent DDT emulsion and a dormant dinitro compound, all at standard dosage. At the end of an 8 day period counts were made of the nymphs on sprayed samples and unsprayed checks, which showed the following results.

SERIES	NYMPHS DEAD
Check	72.5%
Dormant Oil	92.9
DDT Emulsion	96.4
Dinitro Compound	95.7

As soon as weather and ground conditions allowed, the infested area in the blueberry plots were sprayed with a power outfit and quad nozzle using No. 3 discs and 250 to 300 lbs. pressure. The 3 materials were applied and the bushes thoroughly covered.

Records taken 8 days later were as follows:

SERIES	NYMPHS DEAD
Check	77.5%
Dormant Oil	98.3
DDT Emulsion	90.4
Dinitro Compound	98.2

Observations on the seasonal development of the scale were made on the unsprayed plants. The nymphs for the most part matured during June. Eggs hatched by July 7 and by July 16 crawling nymphs were observed on the leaves. It was quite obvious at that time, that very adequate control had been secured on the bushes sprayed with the dormant oil and the dinitro compound. By late July foliage on the checks and bushes sprayed with DDT emulsion had begun to show considerable blackening by sooty fungus.

[1] Kindly determined by Professor Miriam A. Palmer.
[2] Furnished to the Wyoming Experiment Station by Monsanto Chemical Company.

Final counts of scale nymphs on both sprayed and untreated plants were made September 23 and the following data recorded.

SERIES	SCALES PER LEAF	PER CENT REDUCTION
Check	168.2	—
Dormant Oil	.3	99.8
Dinitro Compound	.1	99.9
DDT Emulsion	132.6	21.16

In late fall as the plants were going into the winter, the check bushes and those sprayed with DDT emulsion were very heavily infested. Both leaves and stems were literally covered with young immature scales. In contrast, the plots sprayed with dormant oil and with the dinitro compound were practically free from scale.—1-23-41.

Dust Treatments for Fall Armyworm Control in North Carolina

WALTER M. KULASH, *North Carolina Agr. Expt. Station, Raleigh*

The fall armyworm, *Laphygma frugiperda* S. & A., is an annual pest of corn, grasses, and legumes in North Carolina. This pest does not reach epidemic proportions every year. In 1947, however, early summer records showed that the fall armyworm might become a menace to legumes, grasses, and pastures in North Carolina and reports from the northern sections of South Carolina told of extensive damage by fall armyworms. In late July heavy infestations were observed in southeastern North Carolina. By the first week in September, the entire Piedmont and Coastal Plain areas of North Carolina were heavily infested and severe damage was reported on alfalfa, clover, lespedeza, various grasses, pastures, and lawns. Damage to lawns and golf greens was particularly noticeable because of the burrowing of the larvae to pupate in the soil and the attendant mounds of dirt left on the grass.

CONTROL EXPERIMENTS.—On September 11, two separate cuts of Ladino clover pasture, about 500 feet from each other, were found to be heavily infested with armyworms. Larvae were abundant in all sections of both fields. Poison bran mash (5 pounds of paris green to 100 pounds of bran) was broadcast over one of the 10-acre fields. This treatment did not noticeably reduce larval activity. The other field was divided into four equal sections and each section received a different dust treatment as shown in table 1.

Table 1.—Results of Treatments

TREATMENT	DAYS AFTER DUSTING: 1 Number Larvae Alive	1 Number Larvae Moribund	1 Number Larvae Dead	2 Number Larvae Alive	2 Number Larvae Moribund	2 Number Larvae Dead
20% chlorinated camphene	3	1	6	3	1	6
5% chlordan	10	0	0	5	0	5
3% gamma BHC and 5% DDT	2	0	8	1	0	9
Check	10	0	0	10	0	0

Dusts were applied at the rate of 10 pounds per acre with a rotary type hand duster. Examination of treated areas was made at 1 and 2 days after dusting to check the effect of the dust treatment. Two sample counts of worms were made in each section of the field on each date. In each count, the soil surface was examined until a total of 10 worms was found. The average of two counts for each section is shown in table 1.

The result of the dust treatments indicated that the combination dust of 3 per cent gamma benzene hexachloride and 5 per cent DDT brought about a quicker and greater kill than did 20 per cent chlorinated camphene or 5 per cent chlordan. All three materials evidently were effective in controlling the armyworms in this field. Young Ladino clover sprouts were not attacked after the dustings were made. No phytoxicity was noted in any of the treated areas.

In other instances where armyworms were attacking large acreages in pastures of clover or alfalfa, airplane dusting with 5 per cent DDT dust at 30 to 35 pounds per acre reduced the infestation and the attendant damage to plants.

No attempt was made to check on the residues left by any of these organics in instances where they were used on pastures.

ARMYWORMS IN LAWNS.—Larvae attacking grasses in lawns and golf greens were controlled with one application of a combination dust of 3 per cent gamma benzene hexachloride and 5 per cent DDT. Within 10 minutes after dusting, larvae that had emerged from the soil or from beneath the grass roots began to move around spasmodically. In one lawn treatment, a light shower fell one hour after the dust had been applied thus washing the dust well into thick matted grass. Armyworm activity following the rain was intensified and an average count two hours after dusting showed at least 15 larvae per square yard. In an examination of 1 square yard of lawn surface one day after treatment, armyworms were noted as follows: 4 alive and apparently normal, 2 uncoordinated in their movements, and 17 dead. One application of the benzene hexachloride-DDT combination dust wiped out this infestation as well as a heavy infestation of green June beetle larvae, *Cotinis nitida* (L).—7-12-48.

Host Preference in Japanese Beetles with Special Reference to Grape and Apple

GEORGE S. LANGFORD and ERNEST N. CORY,
University of Maryland, College Park

The food habits of Japanese beetles offer interesting possibilities for study. The beetles have been reported as feeding on over 275 species of plants. The degree or extent to which they attack different species of plants or varieties of the same species varies widely and may be dependent on several circumstances. Hadley (1934) has pointed out that plants are not all relished to the same extent and that in addition to the large number of deciduous trees, shrubs, and flowers especially preferred by the insect, there are many attacked to a lesser extent, the degree of feeding depending on the relative abundance of the beetles in the particular locality. He pointed out that in the absence of preferred food the more tender foliage of plants generally untouched may be eaten.

Less has been published on variations in preference for varieties of plants of the same species, or hybrid plants involving species normally considered as a preferred host. Varietal preference is not uncommon and it is often marked. This is noticeable among apples, grapes, roses, and others. The writers have encountered individual trees among such preferred food as linden and sassafras that were only mildly attacked while adjacent trees of the same species were completely defoliated. These differences indicate good possibilities for developing trees and plants that would be only mildly or seldom attached. Observations on such plants as grape and apple emphasize this possibility.

The foliage of grape and apple is normally considered preferred food. Yet, under identical conditions, the damage for different varieties may vary from complete defoliation to negligible feeding. Over a period of 4 years, observations have been made for information on differences in preference for these two hosts, with rather marked results.

For the basis of this report the grape and apple varieties under observation are divided into four groups, namely:

Group 1—Preferred varieties—Injury very severe.

Group 2—Attractive varieties—Injury moderate to severe.

Group 3—Varieties frequently attacked—Injury moderate.

Group 4—Unattractive varieties—Injury light and occasional.

By the above classification it is not intended to imply that damage may not on occasion be serious in all groups. Frequently, plants that are not normally injured may be severely injured. Irish potatoes provide an outstanding example.

GRAPES.—Grape varieties, as Concord, Worden, Niagara, etc., ordinarily cultivated in the northeastern states are subject to severe injury by Japanese beetles. But, general observation in a community or a vineyard with a miscellaneous assortment of grapes will indicate differences in preference for certain varieties.

Mr. and Mrs. Philip Wagner of Boordy Vineyard, Riderwood, Maryland, have a large and constantly changing collection of grape varieties. This vineyard with the cooperation of Mr. and Mrs. Wagner, has provided interesting information on the relative susceptibility of certain varieties to attack by the beetle under identical conditions. Damage in this vineyard had varied with respect to variety. Certain varieties have been completely and repeatedly defoliated each year, while others have been only mildly attacked or seldom fed upon.

The factors responsible for this variation in susceptibility to injury are not known. However, the character of the foliage seemed to have a bearing. This in turn seemed to be related, in certain instances, to the species of grapes and their proportion in crosses used to develop the varieties. Varieties having thin, glossy and tender foliage were in all instances severely injured while varieties with coarse foliage and covered with a tomentum were much less severely damaged.

Group 1. Preferred varieties—Injury very severe.

Cabernet Sauvignon, Pinot Chardonnay (pure *V. vinifera*, European wine grapes).

Baco No. 1 (*riparia*×*vinifera*, French wine hybrid.)

Delaware (*bourquiniana*×*vinifera*, old American hybrid.)

Seibel 128, Seibel 1000, Seibel 1xx, Seibel 2xx, Seibel 2056, Seibel 6339, Seibel 5409, Seibel 9110, Seibel 5279, Couderc 13, Couderc 4401, Bertile-Seyve 2862, Seyve-Villard 12309. (French wine hybrids of extreme complexity, but with *vinifera*, *lincecumii*, *riparia*, and *rupestris* predominating.)
Norton, Cynthiana (*aestivalis*)
America, Bell, Brilliant, Manito, Rommel, Wine King (Munson hybrids, complex parentage).
N.Y. 10839, N.Y. 11407, N.Y. 11456, N.Y. 13920, N.Y. 20159 (New hybrids from Geneva, New York Experiment Station all with at least two-thirds *vinifera* and usually containing some *labrusca*.)

These varieties are decidedly preferred by beetles and are fed on continuously throughout the season, with complete destruction of the foliage unless preventive measures are taken. Beetles collect on these varieties first and leave them last. The beetles eat the entire leaf except for the main ribs. Most of these varieties have foliage that is thin and glossy. The foliage on a whole is tender and succulent. A few varieties, as Baco and Norton, have leathery foliage, but in none is the foliage woolly or tomentose on the underside.

Most of the varieties have considerable European Grape *Vitis vinifera* L. in them. The American species represented in these crosses include *V. aestivalis*, *V. bourquiniana*, *V. labrusca*, *V. lincecumii*, *V. riparia*, and *V. rupestris*. These containing *V. labrusca* have it in attenuated form so that the characteristics of that foliage are not apparent.

Group 2. Attractive varieties—Injury severe.
Catawba (*Vitis labrusca*×*V. vinifera*)
Delicatessen (*V. vinifera*, *V. lincecumii*, *V. labrusca*)
Cloeta (*V. vinifera*, *V. lincecumii*, *V. labrusca*)

These varieties are very attractive to Japanese beetles. They are only slightly less preferred than those given in Group 1. Complete destruction of foliage may be had under conditions of heavy beetle infestation. They are all varieties that contain considerable proportion of *vinifera* stock. The varieties Cleota and Delicatessen have leaves that are smooth and leathery above, and glabrous on the underside and they are eaten entirely by the beetle except for the principal veins. The leaves of the varieties Catawba and Lomanto are somewhat tomentose or woolly on the undersurface, and when the beetles have finished feeding they resemble fragile lace.

Group 3. Varieties frequently attacked—Injury moderate.
Westfield (predominantly *Vitis labrusca*, and in effect an "improved" Concord)
Iona (Predominantly *V. labrusca* with some *V. vinifera*)
Diamond (Predominantly *V. labrusca* with some *V. vinifera*)

These varieties are much less attractive to beetles than those in Group 2, though they are often injured. Their foliage is characteristic *V. labrusca* foliage. It is coarse and leathery above, and tomentose or woolly below. The leaves, after the beetles have finished feeding on them have the appearance of coarse lace. A considerable amount of the leaf is not eaten.

Group 4. Unattractive varieties—Injury light and occasional.
Champanel (*Vitis champini*×*V. labrusca*—a Munson hybrid)

This variety is definitely not relished by the beetle. Under conditions of heavy infestation vines of this variety even where situated in the vineyard between preferred varieties seldom have more than occasional beetles on them. The foliage and tender shoots of this variety are covered with a thick coarse tomentum. The peculiar woolly foliage is a character of one of its parents, *V. Champini*. Its other parent is *V. labrusca*, a species which predominates in the varieties listed under Group 3, or varieties normally injured only moderately.

In connection with this group or a study of vines not attractive to the beetle, other hybrids of *Vitis champini* and possibly *V. labrusca* should be sought and tested. Hybrids containing generous proportions of these species might provide varieties that could be grown without fear of serious damage from the Japanese beetle.

APPLES.—The foliage of apple varieties as with grape varies widely as to susceptibility to attack by the Japanese beetle. Certain varieties may be completely defoliated while others in adjacent rows are hardly touched.

Over a period of years observations have been made on 1 and 2 year old apple trees growing in nursery rows. Fifty-nine varieties have been studied for susceptibility to injury. These varieties for the most part were grown in the same field and exposed to identical conditions of infestation.

Of the varieties studied those most preferred appeared to be Yellow Transparent, C. P. Close and Starr while those least preferred appeared to be Courtland, Milton and Orleans—on occasions the most preferred varieties would be completely defoliated while those least preferred showed practically no injury. The other varieties ranged between these extremes.

Group 1. Preferred varieties—Injury very severe

Yellow Transparent	Anoken	Lodi
C. P. Close	Crimson Beauty	Smoke House
Starr	Delicious	Twenty-ounce
Red Duchess	Yellow Delicious	Winter Banana
Albemarle Pippin	Gallia Beauty	Wrixparent

Group 2. Attractive varieties—Injury severe

Early Blaxtayman	Opalescent	Winesap
Kendall	Paragon	Jonathan
Lawfam	Red Canada	Richared
Macoun	Turley	Stayman Winesap
Melba	Williams Early Red	

Group 3. Varieties frequently attacked—Injury oderamte

Colora Red York	Grimes Golden	Ohio Red Rome
Baldwin	Hyslop Crab	Red Gravenstein
Dolga Crab	Lobe	Red Northern Spy
Early McIntosh	Northern Spy	Tolman Sweet
	Rome Beauty	
Bountiful (Imperial Winesap)	Medina	
Glenton	Red Warrior	
Improved All Red Jonathan	Rhode Island Greening	
Improved All Red McIntosh	Secor	
Lowry		

Group 4. Unattractive varieties—Injury light and occasional

Courtland	Bontiful Improved White
Milton	Blaxtayman
Orleans	York Imperial
McIntosh	Wealthy

Comparative Tolerance of Small Grains to Greenbugs from Oklahoma and Mississippi

R. G. DAHMS, *Oklahoma Agricultural Experiment Station*, and *U.S.V.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In connection with a study of varietal resistance of small grains to the greenbug, *Toxoptera graminum* (Rond.), an opportunity was afforded during the winter and spring of 1946–47 to compare the tolerance of different varieties of barley, oats, and wheat to greenbugs from Oklahoma and Mississippi. Greenbugs from Mississippi were obtained through the courtesy of A. L. Hamner, of the Mississippi Agricultural Experiment Station.

Greenbugs were collected from winter wheat in the southwestern part of Oklahoma and from oats in the eastern part of Mississippi. The bugs from both sources were collected about November 15, 1946, and upon arrival at the laboratory at Stillwater they were caged on seedling plants of Reno barley growing in 6-inch flowerpots in the greenhouse. The stock cultures were maintained on Reno barley because it was known to be very susceptible to greenbugs. The difference in the tolerance of Reno barley plants to the bugs from the two sources was very noticeable from the beginning. Whenever the plants showed injury, the stock cultures were changed. This was usually every 4 or 5 days for plants infested with Oklahoma bugs, whereas it was always 7 or 8 days for plants infested with Mississippi bugs.

A series of tolerance tests was made with 15 varieties of small grains. Seven varieties were planted in a circle near the edge of a 6-inch flowerpot. When the plants were 5 to 6 days old, they were thinned so that each pot contained only 1 plant of each of the 7 varieties Care was taken to leave plants of about the same height and general vigor. When the plants were 8 to 10 days old, 100 fourth-instar greenbugs 8 days old were caged on the plants. Pots containing plants of the same variety and age were paired, those in one pot being infested with greenbugs from Oklahoma culture and in the other with greenbugs from the Mississippi culture. There were 3 to 6 such pairs of pots in each test. Temperature in the greenhouse during these tests ranged from 48° to 81° F. with an average of 66°. The number of greenbugs on each plant was recorded daily, and the number of days and the number of bug-days of feeding required to kill each plant were ascertained. These records are given in table 1. The data for each variety were treated statistically by the use of Student's T test. The difference in the number of days required for the bugs from the two sources to kill Reno barley plants was highly significant. This difference was not significant for any of the other varieties of barley. Tennex was the only variety of oats that showed a significant difference in the number of bug-days required to kill the plants.

Table 1 shows that, on the basis of bug-days required to kill the plants, the varieties of barley differed greatly in susceptibility to greenbug injury, but that all varieties reacted similarly to the bugs from both sources. Although the data indicate that the varieties of wheat and oats differed somewhat in susceptibility, these differences were much less pronounced than were those in the barleys. However, the comparative susceptibility of all the wheat and oat varieties to the bugs from the two sources was fairly consistent.

In an additional tolerance test with Reno barley, fifteen 6-inch flowerpots were planted to this variety

Table 1.—Comparative tolerance of varieties of small grains in the greenhouse to greenbugs from Oklahoma and from Mississippi.

Variety	C.I. Number[1]	Time Required for Plants to be Killed by Greenbugs from—		Feeding Required for Plants to be Killed by Greenbugs from—	
		Oklahoma	Mississippi	Oklahoma	Mississippi
		Days	*Days*	*Bug-days*	*Bug-Days*
Barley:					
Reno	6,561	10	12	557	666
Tenkow	646	11	11	863	792
Luth	908	11	10	726	691
Peru	707	13	14	1,132	1,456
Unnamed	5,087	20	17	1,954	1,659
Mignon	999	28	30	5,107	3,617
Omugi	5,144	61	56	13,702	15,301
Wheat:					
Wichita	11,952	8	10	384	462
Marquillo×Oro	11,979	9	9	334	414
Comanche	11,673	11	12	371	365
Pawnee	11,669	11	11	344	478
Denton	8,265	11	12	278	357
Oats:					
Tennex	3,169	10	8	366	179
Wintok	3,424	12	11	250	257
Neosho	4,141	12	11	445	304

[1] C. I. in this and the subsequent table refers to accession number of the Division of Cereal Crops and Diseases, Bureau of Plan Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture.

Table 2.—Fecundity and length of life of greenbugs from Oklahoma and Mississippi on seven varieties of small grain in the greenhouse.

Variety	C.I. Number	Nymphs Produced per Parent Aphid from—		Longevity of Parent Aphid from—	
		Okla.	Miss.	Okla.	Miss.
		Number	*Number*	*Days*	*Days*
Barley:					
Reno	6,561	52.7	49.2	39.0	38.6
Peru	707	38.9	35.1	31.9	32.3
Mignon	999	29.9	45.5	24.4	27.7
Wheat:					
Pawnee	11,669	42.7	42.5	39.7	32.9
Marquillo×Oro	11,979	39.5	35.3	28.8	29.1
Denton	8,265	20.9	42.9	26.4	36.2
Oats:					
Tennex	3,169	4.7	15.6	11.2	16.0

and thinned to 5 plants in each pot. When the plants were 5.5 inches high, 5 pots were infested with 30 fourth-instar greenbugs 8 days old from the Oklahoma culture, 5 pots were infested similarly with bugs from the Mississippi culture, and 5 pots were used as uninfested checks. The average life of the plants infested with Oklahoma bugs was 10.6 days, whereas that of the plants infested with Mississippi bugs was 16.8 days, a difference that was highly significant. The average periods required to kill plants were 257 and 540 bug-days, respectively, for Oklahoma and Mississippi bugs. This difference was also highly significant. Measurements of plant height 10 days after infestation showed that the plants infested with Oklahoma bugs had grown 0.8 inch compared with 2.1 inches for those infested with Mississippi bugs. This difference was significant.

The fecundity and length of life of greenbugs from Mississippi and from Oklahoma feeding on seven varieties of small grain are shown in table 2. These data were obtained by caging three adult greenbugs on a seedling plant. The young nymphs were counted and removed from the cage every other day, at which time the parent bugs were removed to a fresh plant. The bugs from each source were caged separately in five cages of each grain variety. Temperature in the greenhouse during these tests ranged from 54° to 81° F., with an average of 67°. Significantly larger numbers of nymphs were produced by the Mississippi bugs than by the Oklahoma bugs on Denton wheat. The Mississippi bugs were considerably more prolific and longer-lived on Mignon barley and Tennex oats than bugs from Oklahoma, but these differences were not significant.

SUMMARY.—Pot tests were made to determine the comparative tolerance under greenhouse conditions of 15 varieties of small grain to greenbugs, *Toxoptera graminum* (Rond.), from Oklahoma and from Mississippi.

Barley plants of the Reno variety made less growth under infestation and were killed in significantly less time by Oklahoma greenbugs than by greenbugs from Mississippi. None of the other varieties showed significant differences in these respects.

On three varieties of barley, two varieties of wheat and one variety of oats there was no statistically significant difference in fecundity between Oklahoma and Mississippi bugs. On Denton wheat the larger number of nymphs produced by the Mississippi bugs was highly significant. Although the Mississippi bugs lived considerably longer and were more prolific than the Oklahoma bugs on Mignon barley and Tennex oats, and also lived longer on Denton wheat, these differences were not statistically significant.

Dermestes and *Saprinus* as Predators and Pests in Fleshfly Rearing

GEORGE B. VOGT, *Communicable Disease Center, U. S. Public Health Service*

Infestations by hymenopterous and mite parasites are always to be guarded against in the course of insectary rearing. This vigilance probably should be extended to include three other pests which are reported here as they were encountered in the course of fly rearing work at Pharr, Texas.[1]

These newly recognized pests of the insectary are widely distributed beetles and, as will be shown, can be seriously destructive to pupae of *Phaenicia pallescens* (Shannon). H. S. Barber[2] has determined these beetles as *Saprinus lugens* Er., generally considered predatory, and *Dermetes ater* Degeer and *D. caninus* Germ., two species considered to be scavengers. The observations which follow may interest the student of insect biology as well as the worker maintaining fly colonies.

The insectary for rearing flies in this case was a tight 6 by 10 by 8 ft. portable frame building which was floorless and placed on loose sandy soil. Temperatures were maintaned between 85° and 92° F. except during the early spring when they ranged between 76° and 84° F. *Phaenicia pellescens* was reared on fresh fish heads, the method employed being little modified from that described by Dorman *et al.* (1938) for rearing *P. sericata*. After the first day of maggot feeding however, an exception to this method was made by transferring each batch of 500 maggots from its small screened pint-sized container to an open 12 inch round shallow pan layered with about 1 inch of sand. Rearing continued in the

[1] This work was carried out in connection with DDT residual studies by the Dysentery Control Project of the U. S. Public Health Service.

[2] Mr. Barber has also kindly given advice and encouragement in the preparation of this paper.

larger container until the resulting pupae were set in emergence cages nine days later. In the same insectary *Musca domestica* was reared by a method very similar to that described by Richardson (1937) except that 2 inches of sand were added to the rearing jars on the fourth day to allow for more favorable pupating conditions. The weekly output of this insectary for each species was a single batch numbering 3000 to 5000 flies.

Late in March adults of *Saprinus lugens* began to appear occasionally inside the insectary and in the rearing pans devoted to *Phaenicia Pallescens*. These beetles did not seem to molest the maggots and little attention was given them. But it was not long before histerid larvae were found as the sand and puparia in the rearing pans were combined for placement in the emergence cage. (Only at times when the sand was shifted did these larvae come into view since they always remained hidden in the sand.) From about 5 to 10 per cent of the puparia in the infested pans had been cut into and their contents partially or wholly consumed. There was no way of determining how many developing maggots may have been preyed upon earlier. By May, with the coming of warmer weather, *Saprinus lugens* disappeared altogether without any effort having been directed towards its control. Such seasonal occurrence is in agreement with observations on this species made in nature at this locality where appearance of the beetles is largely in the early spring.

Of much more serious consequence was the infestation of *Dermestes ater* and to a considerably less extent *D. caninus*. Occasional specimens of these beetles had been noticed about the insectary, but it was not until mid-July that a drastic reduction (from 60 to 90 per cent) in *Phaenicia* production revealed extensive destruction of fly puparia by *Dermestes*. Both larvae and adults of these beetles were observed to attack the pupae but the larvae were much the worst offenders. Usually the puparium was eaten open at one end and the contents consumed, but on numerous occasions much of the pupal case was eaten.

Adequately to protect the pupae of *Phaenicia*, it was necessary to cover the tops of the breeding pans with wire screen (16 meshes to the inch) to exclude flying beetles. Besides this, grease had to be applied to the vertical outer sides of the rearing pans to prevent migrating *Dermestes* larvae of all stages from climbing up and working their way through the screen coverings.

It is possible that the predatory habit of *Dermestes*, as just described, will develop only under such special conditions as existed at this insectary. There follows a discussion of these conditions.

Probably of significance is the fact that fish remains were not allowed to accumulate, but were removed twice each day from the rearing pans and fresh fish added. Also, by about the fourth day after setting of the eggs, when most maggot development was complete, the fish was removed altogether. Such management probably encouraged oviposition by the *Dermestes* but resulted later on in minimization of the supply of dead animal matter available for the developing larvae. Therefore, the *Dermestes* probably of necessity rather than preference resorted to preying upon fly puparia which were readily available.

The fact that *Dermestes* thrives on a diet composed exclusively of dead animal matter is indicated by the infestation by their larvae and adults of fish scraps that each week were set up at the insectary in fly tight cages (maggots were absent) for production of *Hippelates* bait. It is further pointed out that a heavy local population of *Dermestes* was produced at the insectary incinerator where all of the expended fish remains were dumped and rather inadequately burned.

At no time were puparia of *Musca domestica* observed to be molested by either *Dermestes* or *Saprinus* although on frequent occasions these puparia were available. It seems that attraction of these beetles is dependent upon the odors emitted by dead animal matter and not upon the odors emitted by Richardson's medium.

Aside from the damage which *Dermestes ater* and *D. maculatus* may cause in the insectary, it is of interest to consider the possible role these beetles may play in nature against flies. The writer has made no actual field observations, but it seems possible that under conditions of carrion scarcity, *Dermestes* larvae and adults may turn their attention to fly puparia. Such may be the case in garbage dumps as well as under carcasses on the range.

Several European workers have reported that *Dermestes* prey on Lepidoptera in nature. In the Ukraine, Zhikharev (1928) found *D. erichsoni* Gnglb. infesting eggs of *Lymantria monacha* L. and *Porthetria dispar L.* In Bulgaria both pupae and eggs of this last mentioned moth were found by Chorbadzhiev (1926) to be preyed upon by larvae of *D. lardarius* L. and Pyatnitzkii (1938) reports a species of *Dermestes* which in some places in the Crimea destroyed all of the eggs of the gypsy moth.

In the silk industry, *Dermestes* have long been recognized as serious pests, destroying eggs and pupae and damaging cocoons of *Bombyx mori*. *Dermestes verax* Metsch. and *D. coarctatus* Har. are reported as the principal pests in Japan by Yokayama (1925) and by Takio (1937) while *D. lardarius*, *D. undulatus* Brahm, and *D. frischii* Kug. are involved in Russia according to Grunberg (1931) and Kalandadze (1930). *D. lardarius*, *D. vulpinus* F., *V. murinus and D. frischii* are reported in Italy by Canzanelli (1935), Candura (1931) and Malenotti (1925).

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Fly Control in a Small City by Use of DDT-Oil Mist

WILLIAM W. SMITH[1]

During 1947, an experimental project was operated in the City of Hattiesburg, Mississippi (population approximately 25,000), which was designed to test the possibility of providing relief from the muscoid fly problem at a reasonable cost. For purposes of treatment and inspection, the city was divided into seven sections in order to obtain information on the relative fly reductions secured in the several types of areas existing within the city. The fly grill was used for obtaining indices to fly populations for purposes of evaluation. The city sections were classified as follows:

A—Industrial and Negro tenement section
B—Business section
C—Negro and white tenement section, including city dump
D—Residential and scattered business establishments
E—Better residential section
F—Industrial and scattered residences
P—Petal (suburban town)

MATERIALS AND METHODS.—The insecticide used was a 5% solution of DDT in No. 2 diesel fuel (w/v). Application was made by means of a power duster which had been converted to an oil mist sprayer by the Engineering Division of the Communicable Disease Center of the Public Health Service along lines suggested by Dr. G. E. Quinby, J. H. Coffey, T. E. McNeel and others who developed similar apparatus while conducting operations at Florence, Alabama during 1946. In this converted machine, the insecticidal solution is injected into the windblast of the blower through three 80.02 nozzles placed in a ring of copper tubing located at the end of the discharge tube. A small pump is used to force the solution through the nozzles into the windblast which breaks up the solution into fine droplets, producing a mist which may be effective in killing flies as far as 250 feet from the blower if wind conditions are favorable.

In August the injection assembly was changed to one in which the solution was introduced into the windblast through one special nozzle[2] located in the radial center of the windblast tube. This type nozzle appeared to constrict the dispersion of the droplets so that it became more directional, put out larger droplets, and covered less territory per unit of solution used. However, the level of fly indices remained about the same. This modified assembly was not considered as satisfactory as the three nozzles with smaller apertures located on a hollow ring around the mouth of the tube with respect to economy of operation.

City treatments were made once each week throughout the period beginning the last week in June and ending the last week in October, except that no treatment was made during the week ending September 27. During operations, one man drove the 1½-ton truck upon which the spray apparatus was mounted and another man directed the mist by moving the flexible windblast tube with a lever. This lever was attached to the metal sleeve at the distal end of the delivery tube and to a fulcrum which consisted of a ball-and-socket joint mounted on a stationary iron pipe. By grasping the free end of the lever, the operator could easily move the mouth of the delivery tube up and down or from side to side as necessary in properly directing the mist.

Treatment and entomological inspection of city sections required approximately 8 man days per week. Treatments were made by driving the truck slowly down city streets and alleys in the business sections, and down the main streets of the tenement sections with the mist machine operating. The mist was directed at likely fly breeding and congregating places in the alleyways and advantage was taken of any wind movements to help in the dispersion of the mist in residential sections. On the city dump, approximately 50 foot swaths at right angles to the wind were made until the entire dump and neighboring vegetation had been covered by the mist. Treatments were made in the business section early in the mornings before many cars or trucks were present.

ENTOMOLOGICAL INSPECTIONS.—Indices to fly populations were made in approximately 10 areas located in each of the city sections. These index areas were chosen because they contained places most likely to have the maximum number of flies present in that neighborhood and included such places as the city dump, back of poultry and food-handling establishments, hide shops, garbage cans, trash piles, etc. A wooden grill one yard square having 0.75 inch strips and spacings, as described by Scudder (1947) was used in making fly counts. A fly grill count is defined as the number of flies which alight on the grill after they have been disturbed by the grill's placement. In sampling each index area, three grill counts were recorded for each of three stations. The highest single fly count obtained in these nine grill readings was taken as the fly index for that particular area. By averaging these maximum counts from all areas within a city section, the section index was obtained, and likewise by averaging the maximum counts from all sections, the city index was determined.

Ordinarily, grill counts were made in the afternoon following morning sprayings, or on the day following spraying. Pre-treatment counts were made in four instances during the weeks ending June 21, September 27, October 25, and November 1.

DISCUSSION.—The intial, pre-treatment city fly index in June made in five sections was 52, the maximum of section indices being 75. The first weekly treatment reduced the post treatment city index to 2.7, and the highest section index to 3.9. Weekly treatments thereafter indicated that the post treatment city index as obtained shortly after spraying could ordinarily be kept below 3, the only exception being in the week ending October 25 when it was 3.2. Pre-treatment counts in September and October indicated that fly populations make a fast comeback. However, the pre-treatment city index in June was much higher than any of the pre-treatment indices obtained thereafter.

The suburban town of Petal, adjoining Hattiesburg, was treated on 10 occasions during the season, when time was available. Temporary reduction of the fly index was evident after each treatment. The time and materials expended in the Petal treatments are included in the Hattiesburg project costs.

Following a week when no treatment was made the reduction obtained the following week was not materially different from that obtained when regular weekly applications were made. Fly counts made just

[1] S. A. Scientist, USPHS, State Board of Health, Jackson, Mississippi. "Full acknowledgement is made to Mr. L. A. Wood, Area Supervisor, U. S. Public Health Service, CDC Activities, Hattiesburg, Mississippi for his management of the field work in connection with this project."

[2] Manufactured by Spraying Systems Co., Chicago, Illinois. (*Whirljet.*)

before weekly treatments on three occasions showed that the fly index increased from 200 to 400 per cent above that taken after the previous week's treatment. It should be kept in mind that these indices are based on averages of maximum grill counts.

As the index of reduction obtained in all of the different city sections indicated very satisfactory control and since these indices did not appear consistently high or low in any one of the sections from week to week, the sectional index reductions obtained are not considered separately in this report.

COST OF PROGRAM.—In Hattiesburg[1] the actual cost of the program for the four month period exclusive of supervision is itemized as follows:

6900 gallons #2 Diesel oil @0.11	$ 759.00
2800 lbs. technical DDT @0.45	1,360.00
642 man hours @1.10	706.00
642 man hours @0.85	545.70
Initial cost of converted duster	300.00
Repair and miscellaneous costs connected with duster and gasoline for the duster motor	80.00
Gasoline, oil, and repairs for truck	250.00
Total	$4,000.70

Assuming the population of Hattiesburg to be in the neighborhood of 25,000, the total per capita cost would be approximately 16 cents. Roughly, the cost per acre would be 40 cents per treatment.

During the period of this experiment, no changes were made in the basic sanitary measures used by the City of Hattiesburg which might affect fly populations. Garbage collections were made daily in the business sections and daily in residential sections if garbage containers were brought to the front of residences. Weekly garbage collections were made from alleys at the rear of residences. The collections were made in open trucks which carry the garbage to an open dump located at the edge of the city in Section C previously mentioned. At the dump, combustible material was burned, and non-combustible material was scattered, compacted, and covered with soil in so far as possible by a bulldozer. Use of covered garbage containers, covered trucks, and operation of a sanitary land fill undoubtedly would be of assistance in holding the fly population at a satisfactory level.

PUBLIC OPINION.—The main objections to the use of this mist machine in cities are that the spray causes the spotting of automobiles, thus making its use on main thoroughfares somewhat hazardous, and that the comparatively large droplet size prevents the spread of the mist any considerable distance.

After the initial operations had noticeably reduced the number of flies present daily in business establishments, public opinion was very favorable. Care was taken not to spot automobiles with the mist, and the machine was used chiefly on city streets and alleys before traffic became heavy. No complaints on spotting store windows were received. After the program had been in operation about a month, one of the city's most important distributors of fly sprays advertised his entire stock of insecticides at cut-rate prices, the advertisement being directed to out-of-town consumers and admitting that the effectiveness of the fly control program being conducted in the city was the reason for the sale. Many city merchants have indicated their satisfaction with the fly reduction obtained and have requested a similar program from the county health department for next year. The effect of such a program on fly-borne diseases within the city has not been determined.

CONCLUSION.—Very satisfactory fly control as indicated by grill indices were obtained during 1947 in Hattiesburg, Mississippi by weekly use of a 5 per cent DDT-oil solution distributed as a mist by a converted power duster. Prior to treatment, a city-wide fly index of 52 was obtained. A reduction of 94.8 per cent in this index was obtained as a result of the initial spray application, after which the index for the city was held to 2.5 for the season. Fly indices for various sections of the city ranged from 1.9 to 3.2 during this period. All indices were based on maximum fly counts as obtained by fly grill readings.

Such fly abatement was obtained with the equipment mentioned for approximately 4 cents per person per month.

Basic sanitary measures which might affect the fly population of the city remained unchanged during the period of the experiment. Improvements in these measures would probably help in keeping the fly population at a satisfactory level, and might eliminate or greatly reduce the need for supplementary abatement measures.—8-2-48.

[1] Includes also 10 treatments of the neighboring suburb of Petal, Mississippi (population 850).

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Reductions of Fly Indices in the Business District of a Small City by Use of DDT Residual Sprays

WILLIAM W. SMITH[1,2]

On May 12, 1947, an experimental project was set up in Columbus, Mississippi, (estimated population —18,000) to test the possibility of using a 5% DDT water emulsion[3] applied to the garbage, garbage cans and racks, back doors, and back walls of buildings in the business section to reduce the muscoid fly population to such a level that their presence would no longer constitute a nuisance or pest problem in the business establishments of the city. The DDT emulsion was applied from hand sprayers of the compressed air type with three to four gallon capacity by laborers of the city pest control crew. This treatment was used as an adjunct to basic sanitary measures carried out by the city as such measures had previously failed to hold the fly population at a satisfactory low level throughout the year. The regular practice of making daily garbage collections in the business section from covered garbage cans and transporting these collections to the city incinerator in covered garbage trucks was not changed during the period of this experiment.

During the period May 12 to November 1, 10 applications of the 5 per cent DDT emulsion were

[1] S. A. Scientist, U. S. Public Health Service, Communicable Disease Center Activities, State Board of Health, Jackson, Mississippi.

[2] "Full acknowledgement is made to Mr. L. M. Sanders, Sanitation Supervisor of the Lowndes County Health Department, Columbus, Mississippi for his management of the field work in connection with this project."

[3] 3 lbs. DDT (technical grade), 3 qts. Xylene (industrial grade), and 6 ounces Triton X-100 emulsifier composed the 35% stock concentrate used in preparing the emulsion.

Table 1.—Summary of reductions in fly indices as a result of DDT residual spray applications.

Date	Fly Index	Av. No. Days After Treatment	Reduction in Index	Per Cent Reduction in Index
May				
12	29.4	(pre-treatment)	—	—
19	7.5	3	21.9	74.5
26	5.0	3	2.5	33.3
June				
2	9.9	10	0.0	00.0
14	4.2	9	5.7	57.5
21	5.4	16	4.5	45.4
27	5.6	22	4.3	43.5
July				
3	3.5	28	6.4	64.6
10	7.4	35	2.5	25.3
21	6.1	6	1.3	21.3
Aug.				
5	8.1	11	0.0	00.0
22	6.4	8.5	1.7	21.0
30	2.4	4	4.0	62.5
Sept.				
13	14.9	17	0.0	00.0
19	3.7	1	11.2	75.2
30	7.6	12.5	7.3	51.0
Oct.				
6	2.4	1.5	5.2	68.4
29	1.3	13	1.1	45.8

made at the approximate dosage of 200 milligrams per square foot. The intervals between treatments were determined by entomological inspections in which the yard square grill described by Scudder (1947) was used to determine the fly index. A grill count was defined as the number of flies which settled back upon the grill after they had been disturbed by the placement of the grill. The grill was placed only where the maximum congregations of flies appeared present. Three counts were taken at each placement, the grill being removed and then replaced or vigorously shaken between each count. Of the three counts made in this manner, only the maximum count was considered in computing the average or index for the business section of the city. Ten index stations (chiefly back of food-handling establishments) were selected at points in the business section where maximum fly concentrations appeared and these general locations were sampled throughout the year. Additional stations were used from time to time at locations where flies congregated in greater numbers than at the prechosen count stations. In all instances an attempt was made to obtain the highest possible grill counts.

Table 1 indicates the dates on which fly indices were determined, the fly indices as indicated by fly grill counts, the average number of days after treatment, and the numerical and percentage reductions in the indices. The numerical reductions in indices are the differences between the index of a particular day following a treatment and the index of the day nearest preceding the date of the particular treatment considered.

A study of temperature and rainfall during the period of this experiment did not indicate any definite correlation between these conditions and fly indices as determined by grill counts. However, retreatments were made after rains which totaled as much as two inches in any one day. The apparent effectiveness of a treatment over a 35-day period during May and June was probably due to the fact that these months were cooler than normal. Because the entire business area of the city was treated, the use of comparable unsprayed check stations was not possible. As compared with the pre-treatment index, 29.4, the average of all post-treatment indices obtained throughout the period of the experiment was 6.

The satisfaction expressed by merchants of the city and the requests made to the Lowndes County Health Department for a similar program during 1948 indicates that the program was a success at least from the standpoint of public opinion. The result of the program in controlling fly borne diseases is not known at present.

The cost of labor and materials for the project, exclusive of supervision, was approximately $378.32, or $37.38 per treatment. The project was sponsored and financed jointly by the Mississippi State Board of Health, Lowndes County Health Department, and the City of Columbus.

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Comparison of DDT and Chlordan for the Control of the Horse Louse[1]

E. G. Batte and J. C. Gaines, *Department of Entomology, College Station, Texas*

Infestations of biting lice, *Bovicola equi* (L.), on horses produce a dermatitis resulting in a rough coat of hair and a loss in weight. The infested animals are constantly rubbing or biting themselves due to the irritation caused by the presence of lice. The infestation spreads rapidly to all animals in the herd. The lice concentrate in the forelock, mane and at the point of the withers. Seasonal variations in lice populations are quite noticeable. The peak occurs in late winter and early spring. As the temperatures increase in the early summer there is a marked decrease in the lice population. Comparatively few lice survive the midsummer temperatures, but with the onset of cool weather in the fall the population again gradually increases.

The tests herein reported were conducted during the spring of 1948 to determine the comparative effectiveness of chlordan and DDT in controlling the horse louse on Shetland ponies. Sprays containing chlordan in an emulsion and wettable powder and DDT wettable powder were used. The chlordan emulsion contained 40 per sent technical grade chlordan, 10 per cent pine oil and emulsifying agents. Concentrations of 0.03, 0.05, 0.075 and 0.10 per cent chlordan in emulsion were applied. Higher concentrations of chlordan emulsion, above 0.15 per cent, gave 100 per cent control, but were not included in the calculation of the dosage-mortality curve. The sprays made from the wettable powders were applied in concentrations of 0.05, 0.10, 0.15 and 0.20 per cent. The sprays were applied to each animal

[1] Technical article No. 1142, Texas Agricultural Experiment Station. Paid paper.

Table 1.—Dose of each insecticide which was lethal to 50 per cent of the individuals.

INSECTICIDE	PER CENT CONCENTRATION
Chlordan, emulsion	0.043 ± .001
Chlordan, wettable	0.081 ± .001
DDT, wettable	0.099 ± .001

with an electric hand sprayer using 1 quart of spray solution to each animal. This amount was sufficient to wet the animal thoroughly. There was no rain during the period in which the tests were conducted. The average relative humidity was approximately 86 per cent and the average temperature about 82° F.

Lice counts were made before and after each application on an area of 4 square inches on each side of each animal, just above the *tuber spinae* of the scapula. The average number of lice per 8 square inches was 26 before the applications were made. An average of 6 horses were used as replicates for each dosage. The percentage mortalities were calculated using the method described by Abbott (1925). The dosage mortality curves were drawn for each insecticide using the method described by Bliss (1938).

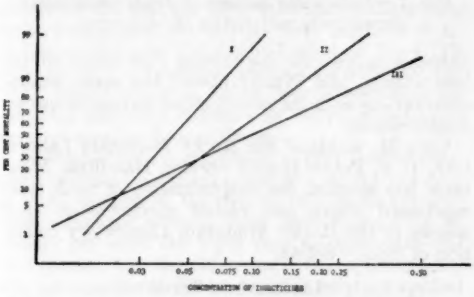

FIG. 1.—Dosage-mortality curves for the toxicity of (I) chlordan emulsion (II) chlordan wettable powder and (III) DDT wettable powder to the horse biting louse.

The dosage-mortality curves in figure 1 show the comparative toxicity of each material. The LD50 of each insecticide is shown in table 1. Chlordan emulsion was the most effective material used against the horse biting louse. The emulsion stood up very well and no injury to the horses was observed. The chlordan wettable powder was more effective than DDT at concentrations above .075 per cent. The wettable powders are perhaps the safest to use and economical control of the horse louse can be obtained with suspension sprays containing either chlordan or DDT.

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A Helicopter for Vegetable Insect Control

GEORGE P. WENE, *Texas Agricultural Experiment Station*, Weslaco

A helicopter was used in three demonstrations for the control of vegetable insects. The first demonstration took place in a 10-acre turnip field heavily infested with the turnip aphid, *Rhopalosiphum pseudobrassicae* (Davis). The turnips were about 10 inches in height and planted in rows which were spaced 36 inches apart. Aphid injury was noticed in the east half of the field. The helicopter was used in applying 3.0 per cent gamma benzene hexachloride at the rate of 30 pounds per acre to the south half of the field. The helicopter was flown about 6 feet above the plants and applied the insecticide in 45-foot swaths. It was interesting to note that the dust was driven in a cloud along the ground for about 30 feet away from each side of the helicopter and a thin cloud drifted another 10 feet. Twenty-four hours later, 35 leaves were selected at random from each of the four areas shown in table 1 for control data. The data in the first table show that this method of application gave excellent control.

Table 1.—Control of turnip aphids with a 3.0 per cent gamma benzene hexachloride dust applied by helicopter.

TREATMENTS	PLANTS AFFECTED BY APHIDS	AVE. NO. APHIDS PER LEAF 24 HOURS AFTER
3.0% gamma benzene hexachloride	Yes	2.5
3.0% gamma benzene hexachloride	No	3.5
Untreated	Yes	49.1
Untreated	No	75.6

The cabbage aphid, *Brevicoryne brassicae* (L), has caused the rejection of hundreds of acres of broccoli for both quick freezing and fresh market purposes. Most of these aphids are found inside the broccoli heads. Rigid wing airplane applications of 30 pounds of 3.0 per cent gamma benzene hexachloride dust to the acre had been used by many growers without any success. A 6-acre field was divided into three 2-acre blocks. The helicopter was used in applying a 5.0 per cent hexaethyl tetraphosphate dust at 40 pounds per acre to the first block. The helicopter was driven about 5 feet above the plants and the insecticide applied in 40-foot swaths. The middle block was used as a check. The helicopter was used in applying the same 5.0 per cent hexaethyl tetraphosphate dust to the third block but at a 50 pound per acre rate. The next day 100 heads in each block were examined closely and the percentage having living aphids inside the head determined. Also, the percentage of plants with living aphids on the leaves was determined. The data in table 2 show that the 5.0 per cent hexaethyl tetraphosphate dust applied by helicopter greatly reduced the aphid infestation in the broccoli heads.

In the third experiment an attempt was made to compare insecticide applications by a rigid wing duster and a helicopter. A large broccoli field was

Table 2.—Control of cabbage aphids on broccoli with a 5.0 per cent hexaethyl tetraphosphate dust applied by helicopter.

Treatments	Pounds per Acre	Number of Plants	Per Cent with Live Aphids 24 Hours After	
			Head	Plants
5.0% Hexaethyl tetraphosphate	40	100	7.0	1.0
5.0% Hexaethyl tetraphosphate	50	100	5.5	2.0
Untreated	—	100	49.5	9.5

divided into two sections. Twenty plants from 5 areas in each section were examined and the number of cabbage loopers, *Trichoplusia ni.* (Hbn.), recorded. The next morning each machine dusted its section with a 1.0 per cent impregnated DDT dust. The rigid wing duster or airplane applied the DDT in 60-foot swaths while the helicopter duster used 48-foot swaths. Three days later, cabbage worm counts were made again in the initial areas examined. The data show that the rigid wing duster gave better control, but actually this difference is too small to be of any significance. It may be well to note that the helicopter blew some of those plants near the machine so much that some of the tops almost touched the ground.

A comparison of helicopter and airplane dusting with dust applications of 1 per cent impregnated DDT for the control of cabbage loopers showed that of 67 cabbage loopers present on the plants 24 hours before dusting with a helicopter, only two survived after 72 hours and of 37 on plants dusted with an airplane none survived.—8-15-48.

Two Interesting Tick Records from Georgia

HARRY D. PRATT[1] and ROBERT H. MCCAULEY, JR.[2]

Dermacentor albipictus (Packard), the "winter tick" of cattle, horses, and big game animals, has never been recorded previously from Georgia according to the distribution maps of Cooley (2) and Bishopp and Trembley (1). It is therefore of interest to record the presence of many specimens of *Dermacentor albipictus*, chiefly males, from a Virginia deer shot on November 22, 1947, at Camp Stewart, near Clyde in Bryan County, Georgia, near the Georgia coast.

This same deer was heavily infested with the black-legged tick, *Ixodes scapularis* Say. Nineteen pairs of these *Ixodes* were found *in copula* on the deer. Since there is little information on the biology of these ticks, the picture of these ticks mating (fig. 1) should be of some interest. The picture shows a male mating with an engorged female, but several female specimens found *in copula* were very small, indicating the probability that a blood meal is not necessary before mating. Craig & Faust (1947) have described this process as follows: "At the time of mating the male seeks out a female attached to a host . . . crawls between her and her support, and with the ventral surfaces of the 2 ticks apposed, by means of his mouth parts distends the vagina, discharges a spermatophore, and then with his mouthparts introduces the spermatophore into the vagina." Hooker (1908) has recorded a similar observation,

[1] Scientist, Laboratory Division, Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.
[2] Senior Assistant Sanitarian (R), Technical Development Division, Communicable Disease Center, U. S. Public Health Service, Savannah, Georgia.

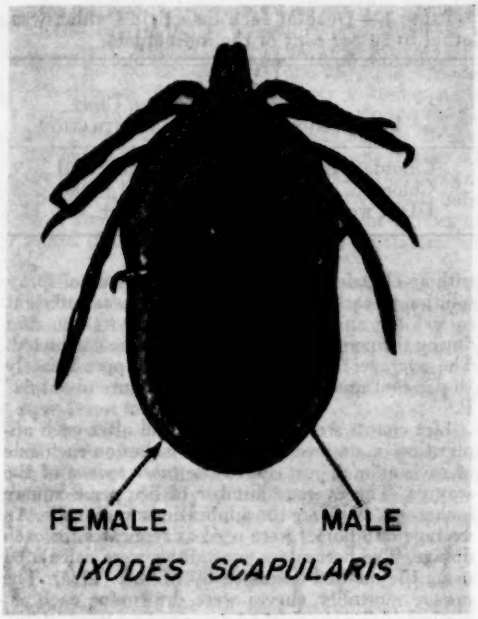

FIG. 1.—Composite picture of *Ixodes scapularis* showing characteristics of both sexes.

although in his case the mating took place off the host animal, and Wheler (1906) has made similar observations with the closely allied European species *Ixodes ricinus*.

Glen M. Kohls of the Rocky Mountain Laboratory, U. S. Public Health Service, Hamilton, Montana, has checked the determination of both ticks mentioned above and placed specimens of each species in the Rocky Mountain Laboratory collection of ticks.—8-2-48.

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Field Tests Versus Laboratory Tests with DDT Against the Pea Weevil

TOM A. BRINDLEY, RALPH SCHOPP, and FRANK G. HINMAN, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

In 1944 Schopp & Brindley (1944) reported that DDT in laboratory tests showed little toxicity to the pea weevil, *Bruchus pisorum* (L.), whereas in subsequent field experiments this insecticide was

[1] In cooperation with the Idaho Ag. Exp. Station.

found to be effective for the pest (Schopp *et al.* 1948).

In 1944, for example, in a randomized-block experiment with 21 replicates a 0.75-per cent rotenone dust reduced weevil populations by 98.2 per cent in 2 days, whereas a 5-per cent DDT dust reduced populations by 99.2 per cent in the same period. The control with both materials was so high that the relative effectiveness of the two could not be determined. Further experiments were conducted in 1945 on 0.10-acre plots with dust mixtures containing 2.5, 5, and 10 per cent of DDT in pyrophyllite. Applied at the rate of 20 pounds per acre, each of these materials reduced weevil populations by 99.3 per cent, whereas a dust containing 0.75 per cent of rotenone reduced populations by 97.8 per cent.

Experiments in 1946 were designed to determine the length of time DDT would remain effective under field conditions, the minimum concentration of DDT that would control the pest, and the most effective rate of application. Applied at the rate of 20 pounds per acre, 2.5 per cent DDT dust was significantly better than 1.25 per cent, but not enough different from 5 per cent to show significance. When the 5-per cent DDT dust was applied at the rate of 10, 20, and 40 pounds per acre, there was little difference in the control obtained from the 20 and 40-pound applications. The difference between the 10-pound and the other applications was due primarily to less reduction in the number of weevils on the first day after dusting. All three mixtures were superior to a 1-per cent rotenone dust. In this experiment the residual effect of the DDT exceeded that of rotenone. Indications were that the DDT treatments were losing their effectiveness on the sixth day, but increases in weevil populations were too small to be significant.

Additional data accumulated in 1947 showed that, when mixtures containing 1.25 2.5, and 5 per cent of DDT applied at the rate of 10 pounds per acre were compared with a 5-per cent mixture at 20 pounds per acre, the 5-per cent mixture gave the best results, but the difference between treatments was not significant. The 5-per cent mixture applied at this rate also gave better results than the 2.5-per cent mixture applied at 10, 20, or 40 pounds per acre.

From field-plot experiments conducted during the last three seasons, it is obvious that DDT is effective for pea weevil control. Applications of 5-per cent DDT dust at the rate of 20 pounds per acre were adequate for pea weevil control under ordinary conditions, and gave some leeway in adverse weather. However, lower dosages were effective. Almost as good control was obtained with 10 pounds of 2.5-per cent DDT dust as with 20 pounds of the 5-per cent dust. Increasing the dosage from 20 to 40 pounds made very little difference in control.

The reason for the discrepancy in the results obtained with DDT in the laboratory and the field is not known, even though it has been the subject of repeated experiments. The results of this work show that laboratory tests are not always indicative of performance of an insecticide in the field.—6-11-48

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Notes on an Imported Fire Ant

CLAY LYLE AND IRMA FORTUNE, *State College, Miss.*

In the spring of 1947 farmers in the vicinity of Artesia, Mississippi, reported the presence of an ant which was causing some uneasiness among the commercial hay producers of that locality on account of the numerous large mounds it built in meadow. Investigation and the identification of specimens forwarded to Dr. M. R. Smith in Washington revealed that the ant was *Solenopsis saevissima* var. *richteri* Forel, a fire ant native to Argentina, but introduced into the United States some time prior to 1920 at Mobile. Until 1947 it had been recorded in the United States only from Mobile and Baldwin Counties, Alabama, and from George and Jackson Counties, Mississippi. Scouting by the Mississippi State Plant Board in 1947 revealed the ant in seven additional counties—Lowndes, Clay, Oktibbehai Noxubee, Lauderdale, Greene and Wayne. It may, be present in other counties in both Mississippi and Alabama.

The ant builds mounds of soil which may reach 2 to 3 feet in diameter and height. Locations along ditches or in low spots near water are preferred. The interior of the mound is honeycombed with tunnels which are lined with a hard, cement-like substance. The ants live near the top of the mound during the winter but go down below the ground level in the hottest part of the summer. The brood nest is usually near the center of the mound and is moved up or down as the soil water level rises or falls.

Preliminary observations in an unheated laboratory during the latter part of October and in November indicated that about one month was spent in the larval stage and about 25 days as a pupa under the conditions existing.

This ant has the usual food habits of fire ants. They prefer meat, bread and other foods containing grease or proteins when they invade houses. They swarm on pieces of bacon but show no interest in sweets such as preserves or the government formula Argentine ant poison which contains sugar and honey. They were observed attending mealybugs which was the only evidence of attraction to sweets. In George County a large field of corn was completely destroyed just as the grains sprouted, the ants eating out the germ portion of the grain. Injury to the bark of young citrus trees at the ground level has been observed. The killing of farm livestock at birth has also been reported. The building of many mounds in hay fields is very objectionable. This ant is very aggressive and is a vicious stinger, in summer often occurring in numbers on weeds and tall grass several feet from the nest and immediately attacking any intruder. It is reported so prevalent and vicious in Irish potato fields near Mobile as to make it difficult to secure labor for harvesting.

Several chemicals have been found very effective in laboratory tests and in treating mounds in the field, including 10 per cent DDT, 5 per cent gamma benzene hexachloride, 25 per cent chlorinated camphene, and 5 per cent chlordan. These were applied in dust form, blowing them through the tunnels in the mounds with a small plunger duster having a short spout to penetrate the outside crust of the mound. In extensive field tests a 5 per cent chlordan dust has been much more effective than a 10 per cent DDT dust. Preliminary tests with calcium cyanide and other fumigants seem to indicate that they are not quite as effective as the chlorinated hydrocarbons. Late winter and early spring months seem to be the best time for applying the dust

treatment as the ants are then concentrated near the top of the mound. The State Plant Board of Mississippi has already received a legislative appropriation of $15,000 to initiate the eradication of this pest in the northeastern part of the state and to begin control work in the southeastern section.—6-18-48.

A Comparison of DDT and Dichlorodiphenyl Dichlorethane as Larvicides for *Aëdes* Mosquitoes

RICHARD M. BOHART, *University of California, Davis*

Two of the most important pest mosquitoes in California are *Aëdes squamiger* (Coquillett) and *A. dorsalis* (Meigen). Their larvae occur together in brackish water along the coast as far north as Marin County, and *A. dorsalis* extends its range over much of northern United States, Canada, Europe and Asia. Both species prefer open grassy breeding areas but *A. squamiger* is restricted to brackish water. The adult females often swarm on both man and domesticated animals in meadows and salt marshes or may travel many miles to cities or to wooded canyons.

Aëdes squamiger larvae have been considered more difficult to control than *A. dorsalis* and this has been attributed to the saline water and heavy vegetation in the preferred breeding places. However, the absence of a satisfactory means of distinguishing the larvae has prevented an accurate comparison. In taxonomic studies to be reported elsewhere, it was found that the 2 species could be readily separated in all larval instars by the proportionately longer lateral hair of the anal segment in *A. squamiger*. Subsequent laboratory tests carried out by the writer indicate that *A. squamiger* is generally more resistant than *A. dorsalis* to larvicides.

DDT has been widely used in control of both species but its use has been restricted by fear of damage to fish, waterfowl and cattle along the coast and to grazing animals of inland irrigated pastures.

Of the organic materials which have been proposed as substitutes for DDT in mosquito larvicides, dichlorodiphenyl dichlorethane[1] appears to be the most promising. Because of its high toxicity to larvae and its reputedly low toxicity to mammals and fish, its use in mosquito control is steadily increasing.

Only a few critical reports comparing the two materials as larvicides have been published. Deonier & Jones (1946) in tests against *Anopheles quadrimaculatus* Say found dichlorodiphenyl dichlorethane slightly superior in acetone solution. Using 20 larvae per test and 3 replications, mortality in 48 hours with DDD was 100 per cent at one part to 200 million and 95.0 per cent at one part to 400 million. Corresponding dosages of DDT gave mortalities of 96.6 per cent and 81.6 per cent. Also, the dichlorodiphenyl dichlorethane indicated greater residual toxicity in a test in which larvae were placed in one part to 100 million 2 to 9 days after preparation of the mixture. Similar results were reported by Deonier *et al.* (1946) in comparative tests with 14 materials related to DDT. The only other material of equal toxicity was 1-trichloro-2,2-bis (p-bromophenyl) ethane. Herms (1946), working with *Culiseta incidens* (Thomson) reported that dichlorodiphenyl dichlorethane was about equal in efficiency to DDT, giving consistently high mortality at one part to 20 million but varying results at greater dilutions. Ginsburg (1947) compared the effect of DDT, 2 isomers and 2 analogues on larvae of *Aëdes aegypti* (L.) and on goldfish. He used 4 replications of 50 to 60 larvae and added larvicides dissolved in ethanol. After 48 hours at 1 part to 100 million, mortality with dichlorodiphenyl dichlorethane was 65 per cent and with DDT was only 35 per cent. Results were about equal in more concentrated mixtures. The former was much less toxic than DDT to goldfish, having no apparent effect at one part to 4 million, whereas this concentration of DDT was lethal.

MATERIALS AND METHODS.—The laboratory testing technique finally adopted has been previously described (Bohart 1948). Larvae were collected from brackish water in the third instar and reared in 0.5 per cent sodium chloride solution. Food was added daily in the form of ground dog biscuit and yeast. Young fourth instar larvae were used in the 48 hour tests and were transferred on a net-covered wire loop from rearing pans to heavy china cups. The latter were of 2 sizes, 100 cc. and 200 cc. and accommodated 10 and 20 larvae respectively. No food was provided during the test period and this did not appear to affect well-fed larvae. Dilutions of larvicide were prepared from a stock mixture of 20 grams of technical grade insecticide made up to 100 cc. in xylene containing 10 per cent emulsifier.[2] A graduated 1 cc. pipette was used to transfer the diluted mixtures of one part to 1 million by weight in distilled water (disregarding weight of the solvent and emulsifier). After 48 hours larvae whidh were unable to coordinate their movements, that is, to come to the surface, to go to the bottom, or to swim in a normal manner were presumed on the basis of previous tests to be mortally affected. Used containers were cleaned by 3 scrubbings in hot detergent solution and exposure to 100 C. for an hour in a drying oven.

Table 1.—*Aëdes squamiger*—Toxicity of DDT and dichlorodiphenyl dichlorethane emulsions; water containing 5 grams salt per liter; water temperature about 23° F.; length of test period 48 hours.

Larvicide and Dilution by Weight in Water	Number of Tests	Number of Larvae	Per Cent Mortality
DDT			
1– 10 million	11	160	93.8
1– 20 million	2	20	85.0
1– 30 million	10	170	51.8
1– 50 million	11	170	36.5
1–100 million	8	140	5.0
1–200 million	2	20	0
Dichlorodiphenyl dichlorethane			
1– 10 million	3	30	100.0
1– 20 million	1	10	100.0
1– 30 million	6	100	87.0
1– 50 million	10	120	75.8
1–100 million	8	110	51.8
1–200 million	6	90	30.0
1–400 million	3	30	13.3
Checks	13	310	2.3

[1] 1,1-dichloro-2,2-bis (p-chlorophenyl) ethane.

[2] *Triton X 100* emulsifier. Rohm and Haas Company.

EXPERIMENTS AND RESULTS.—Tables 1 and 2 summarize the 109 tests made on the 2 species using DDT and dichlorodiphenyl dichlorethane emulsions. Considerable variation in mortality figures was encountered. In general the more robust larvae were more difficult to kill. Also, larvae kept for a week or more in the laboratory were more susceptible than those brought in from the field and used the following day. However, tests were comparative and DDD was consistently superior to DDT. In the case of *Aëdes squamiger* the median lethal dose of DDT was about 1 part to 30 million, and of dichlorodiphenyl dichlorethane was about 1 part to 100 million. A dose of one part to 10 million of the former caused 93.8 per cent mortality and 1 part to 20 million of the latter caused 100 per cent. In the case of *A. dorsalis* the median lethal dose of DDT was about one part to 200 million, and of dichlorodiphenyl dichlorethane was between one part to 400 million and one part to 800 million. Complete toxicity was achieved with one part DDT to 30 million and one part dichlorodiphenyl dichlorethane to 200 million.

Table 2.—*Aëdes dorsalis*—Toxicity of DDT and dichlorodiphenyl dichlorethane emulsions; water containing 5 grams salt per liter; water temperature about 23° F.; length of test period 48 hours.

LARVICIDE AND DILUTION BY WEIGHT IN WATER	NUMBER OF TESTS	NUMBER OF LARVAE	PER CENT MORTALITY
DDT			
1– 30 million	3	20	100.0
1– 50 million	3	44	97.7
1–100 million	3	55	76.3
1–200 million	3	56	46.4
1–400 million	3	47	10.6
Dichlorodiphenyl dichlorethane			
1– 50 million	2	30	100.0
1–100 million	3	48	100.0
1–200 million	3	54	100.0
1–400 million	3	49	79.6
1–800 million	3	33	9.1
Checks	3	62	6.5

SUMMARY.—In laboratory tests with DDT and dichlorodiphenyl dichlorethane in xylene emulsions against *Aëdes* larvae collected in salt marshes of central California, the latter compound was found to be two to three or more times as toxic, depending upon the concentration used. Also, *Aëdes squamiger* was found to be much more resistant to both materials than was *A. dorsalis*. Both of these discoveries may have a practical application since (1) dichlorodiphenyl dichlorethane has been considered as a substitute for DDT where danger of residues to man, domesticated animals and wild life is a factor, and (2) *A. squamiger* or *A. dorsalis* may frequently be found in "pure culture" and can be treated with different dosages of larvicide when so found.

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Laboratory Effects of Parathion on the Two-Spotted Mite[1]

R. G. ROSENSTIEL, *Corvallis, Oregon*

The two-spotted mite, *Tetranychus bimaculatus* Harvey, was reared in a greenhouse on leaves of Blue Lake beans. Pieces of bean leaves bearing 40 to 50 spider mites in various stages were placed on the lower leaves of individually potted test plants four days before the time for testing. Sweet peas were used as test plants in the following experiments. The sweet peas were planted in flats, and after two full leaves appeared they were transplanted to small pots. They were ready to receive the mites three days after they were transplanted. When ready for examination, the leaves bearing the mites were removed and the mites were observed with the aid of a binocular microscope.

In the tests recorded in the following tables, a concentrate of 15 per cent wettable parathion, was used in the form of a spray on the mites. Application was by means of a quart size hand sprayer, which delivered a fine mist of spray. The spray was applied from beneath the leaves until the liquid began to drip.

Table 1.—Effects of parathion dilutions on adult two-spotted mites examined December 9.

PLANTS	DILUTION 15 PCT. STOCK—100 GAL.	AVERAGE PER PLANT		PER CENT CONTROL
		DEAD	ALIVE	
4	Untreated	0	158	0
4	1 oz.	32	19	63
4	4 oz.	55	25	69
4	16 oz.	67	4	94

The dosage recorded in ounces in table 1 contained only 15 per cent active chemical which is indicated in the column heading. In this table as well as table 2 the mites were sprayed on December 6. Table 1 shows 94 per cent control when one pound of 15 per cent parathion per 100 gallons of spray was applied. Lower dosages were not very effective.

The mites denoted by "Resting" in table 2 were quiescent stage larvae, protonymphs, and deutonymphs in contrast to the active stages. Resting stage mites were immobile when touched and had

[1] Contribution from the Department of Entomology. Oregon State College Corvallis, Oregon.

Table 2.—Residual effects of 15 per cent parathion used at 1 pound per 100 gallons of water on two-spotted mites.

Date	Plants	Notes	Active Average				Resting Average		
			Eggs	Dead	Alive	Per Cent Control	Dead	Alive	Per Cent Control
Dec.									
13	4	Untreated	283	2	106	2	0	17	0
20	6	Untreated	297	4	64	9	0	11	0
13	6	Residual Effect	14	50	1	98	11	0	100
20	6	Residual Effect	2	54	1	98	8	3	73
13	6	Reinfested Dec. 9	40	63	19	77	11	3	78
20	6	Reinfested Dec. 16	23	47	24	66	20	4	83

colorless, usually folded legs in comparison to the active stages. Dead mites were shrivelled and dark in color. Only unhatched eggs were recorded.

Table 2 shows residual toxic effect of parathion when the test plants were reinfested at 1 and 2 week intervals after receiving treatment. The non-reinfested plants continued to show good control of both active and resting stage mites for the two week test interval. The mite eggs were shrivelled and dry after 2 weeks on the non-reinfested plants.

The plants reinfested with mites showed fair control, 77 and 66 per cent after 1 and 2 weeks, respectively. Only a few resting stage mites were observed on the reinfested plants, but the results indicate that they are also susceptible to the residual effect of parathion for at least 2 weeks under conditions of this test.—1-23-48.

Tests of Toxicants for the Peach Silver Mite

F. W. CARLSON, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Peach silver mite, *Vasates cornutus* (Banks), has been found in every orchard examined by the author in the Yakima Valley of Washington. The infestation varies from a few to several hundred mites per leaf. When heavily infested, the leaves over the entire tree have a silvery appearance.

Early in the fall (about September 1) in 1947 these mites move from the leaves to the fruit and leaf buds where they spend the winter. Severely infested buds are either killed or become too weak to produce fruit. Early in the spring the mites can be found feeding on the blossoms, young peaches, and leaves. No damage to the young peaches has been noted, as they are well protected by fuzz which the mites do not seem to penetrate. However, they appear to get some nutriment from the fuzz, for 25 to 30 mites have been counted in a small area of the peach.

Insecticides were tested on July 18 by spraying small branches on a heavily infested tree with a hand sprayer. The treated branches were examined on July 21 and 22. Counts were made by taking five leaves at random from each branch and counting the live mites on both sides of each leaf. The toxicants used and the results obtained are given in table 1.

[1] Acknowledgment is made to W. E. Westlake of this Bureau for suggestions and advice.

Table 1.—Effect of various insecticides applied as sprays against the peach silver mite on peach.

Toxicant	Amount[1]	Mites per Leaf
Tetraethyl phosphate[2]	1 pt.	0.0
Nicotine sulfate (40% nicotine)	1 pt.	0.3
Parathion 15%	1 lb.	1.0
Disodium ethylene bisdithiocarbamate	2 qt.	
Hydrated lime	0.5 lb.	1.0
Zinc sulfate	1 lb.	
Lime-sulfur	1 gal.	1.8
Chlorinated camphene	1 pt.	21.5
Bis(*p*-chlorophenoxy)methane	1 lb.	24.5
Check, untreated	—	395.0

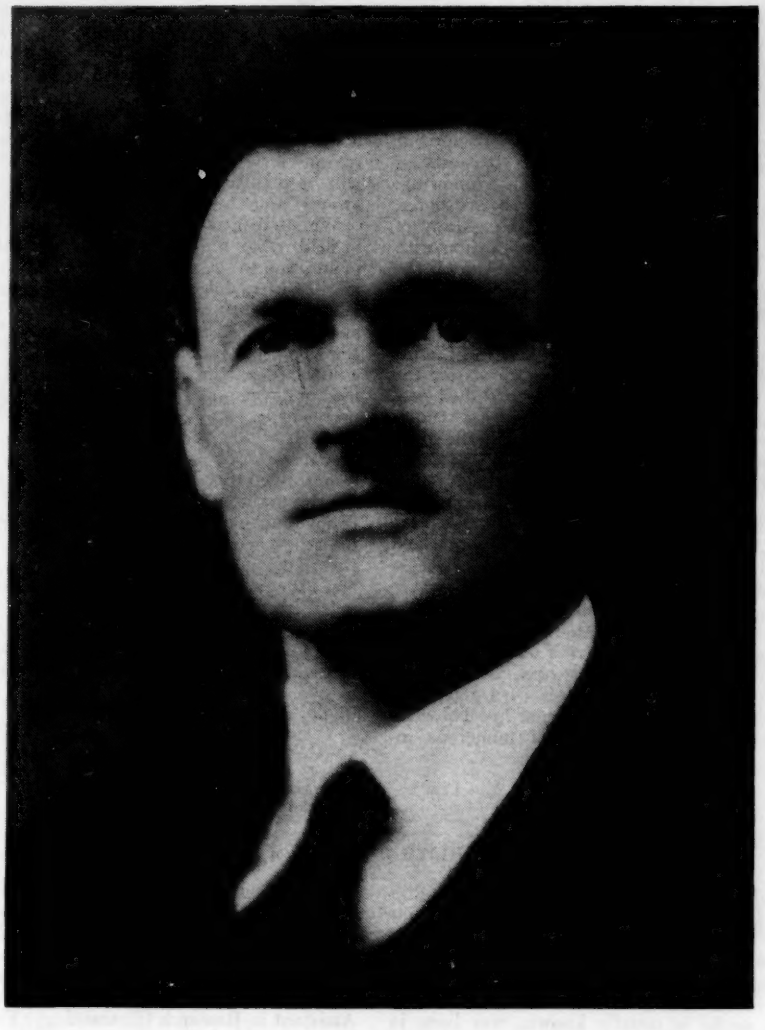
[1] Amounts given are per 100 gal. of spray.
[2] Active ingredients: tetraethyl phosphate, probably pyrophosphate, 9%; other organic phosphates 16%.

On July 24 the same tree was sprayed with 1 pound of 15 per cent parathion to 100 gallons, by means of a small bucket pump. As this was a small tree, only 5 gallons of spray were required to drench it. However, a much better job could have been done with a power sprayer and more pressure.

On July 28 no live mites were found. At the time of a second examination, on August 12, the untreated tree had an average of 495 live mites per leaf; on the sprayed tree the infestation averaged 13 live mites per leaf. These mites may have hatched from eggs that were present at the time of spraying, or they may have been carried over by wind or birds from adjoining trees.

No injury to fruit or foliage was noted from any of these materials.—3-13-48.

OBITUARIES



HUGH GLASGOW

Hugh Glasgow, 1884-1948

Dr. Hugh Glasgow, Head of the Division of Entomology, New York State Agricultural Experiment Station, Geneva, died July 17, 1948, after a severe illness. Although afflicted for more than 20 months, he recovered sufficiently to attend fully to office and field duties from about July 1, 1947 to April 7, 1948. He was born in Tennessee, Illinois, November 17, 1884, and was married December 28, 1935, to Dr. Beulah Ennis who survives him. Others of his family living are a brother, Dr. Robert D. Glasgow, State Entomologist of New York at Albany, and two sisters, Dr. Ruth Glasgow and Dr. Grace Glasgow, both of Baltimore, Maryland.

Hugh received from the University of Illinois the degrees of A.B., 1908, and Ph.D., 1913. During this university period, he held the following positions: Nursery Inspector for the Illinois State Natural History Survey, summers of 1908, 09 and 10; at the University, Assistant Entomologist, 1910–12 and Instructor in Entomology, 1913–14. Appointed as Associate Entomologist in the Geneva Station in 1914, he was advanced with the following titles: Associate in Research, 1919–29; Chief in Research, 1929–38; Chief in Research and Head of Division, 1938–41, when the title was changed to Professor of Entomology and Head of the Division, 1941–48.

He was a member of Sigma Xi; a fellow of the AAAS; a member of the Entomological Society of America; and a member of the American Association of Economic Entomologists, serving as Vice President and Chairman of the Eastern Branch, 1944–45.

Traveling in England, France, Germany and Spain for several months in 1929, he visited experiment stations, research institutions and workers in the field of entomology and related sciences. During the autumn of 1941, in company with Mrs. Glasgow, he visited experiment stations in Cuba and in a number of the southern states.

The insect investigations which he conducted included various species of fruit and vegetable pests. From 1914 to about 1925 about equal portions of his time were devoted to each of these two groups but gradually more attention was given to pests of vegetables. The fruit insects included the following: rosy apple aphid, apple red bug, peach tree borer, sinuate pear borer and cherry fruit flies. Many of the investigations were made in collaboration with Station entomologists and with members of the Division of Plant Pathology. For example, from 1914 to 1931, studies by Dr. P. J. Parrott, the late Professor F. C. Stewart and Dr. Glasgow were made each year on the control of apple scab, rosy apple aphid, codling moth and other apple pests for the purpose of developing effective spray and dust programs for apple orchards. The results of these studies formed the basis for recommendations of apple spray programs used by the growers from 1915 to about 1938, when the introduction of a number of new insecticides and fungicides changed the recommendations considerably. Studies of fruit flies were made in cooperation with Dr. F. L. Gambrell and established the recommended control for these insects from 1926 to the present.

Dr. Glasgow made important contributions to the control of a number of vegetable insects, especially the following species: cabbage root maggot, cabbage aphid, the imported cabbage worm, the cabbage looper, pea aphid, pea weevil, seed corn maggot in beans, spinach miner and carrot rust fly. These included biological studies, tests of numerous insecticides, determination of proper timing of applications, development of new spray and dust mixtures, and especially the adaptation and development of machinery for making effective treatment. His inventiveness and penchant for machinery were important factors in readjusting and redesigning imperfect outfits until they gave satisfactory results. His experiments were made with great care and thoroughness. His writings (40 titles) are concise and explicit and are founded on an abundance of data and a wealth of experience and observations, for which reasons his conclusions have not been refuted. He will be greatly missed by the fruit and vegetable growers and also by leaders in the canning industry.

While Head of the Division, he continued active in field research even though it required much time in addition to the regular hours of work. Meanwhile, he executed his administrative duties and also helped those associates who were in need of advice and assistance. Supervision was more by example than precept. Emphasis was placed on building up a strong department by aiding the less experienced men in developing techniques that would solve their problems, even assisting them in the field at critical periods.

Although his entomological achievements were important, Dr. Glasgow will be remembered by all for the grand man he was, being helpful to others, companionable, unassuming and of the highest integrity. Free from all pettishness, he was not disturbed by situations that would worry most men and his equanimity in trying circumstances was remarkable. Interested in many phases of nature, he was a delightful companion on field and camping trips and ever ready to assume more than his share of the drudgery. In his passing, entomology has lost a splendid worker, his associates a faithful and highly esteemed friend.

F. Z. HARTZELL

Samuel Willard Harman, 1894-1948

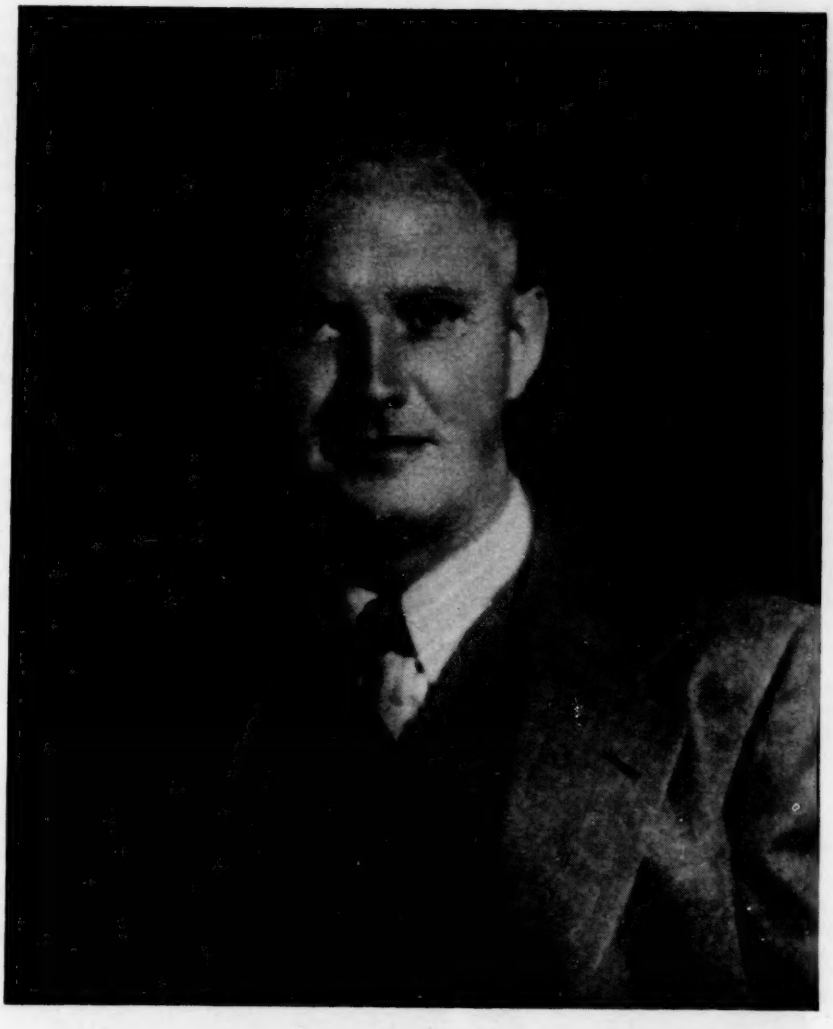
The sudden death of Samuel Willard Harman on March 17, 1948, shocked all his friends and acquaintances. He seemed in good health and was directing work in one of the station orchards on March 16. He passed away in his sleep at home from a heart ailment.

Willard, as he is usually known, was born in Geneva, February 24, 1894, and was married December 25, 1934 to Mary N. Covert, who with a son survives him. Other members of his family remaining are his father and mother, Mr. and Mrs. Milton H. Harman, and two brothers, Milton M., of Geneva, and John H., U. S. Bureau of Entomology and Plant Quarantine, residing at Trenton, N. J.

After receiving the B.S. degree in horticulture from Michigan Agricultural College in 1917, he entered Iowa State College as laboratory assistant in the Department of Horticulture. That year, however, was the beginning of America's participation in World War I, and Willard enlisted in the navy, where he served as ensign from 1917 to 1919. With the termination of the war, he entertained the idea of entering some business where he could make use of his training and at the same time be near to nature. He first entered the employ of the C. S. Powell Lumber Company, Portsmouth, Virginia, in a supervisory capacity, 1919–20; then went with the Davey Tree Expert Company, Kent, Ohio, where he learned tree surgery, 1920–21; then in a supervisory capacity with the Department of Parks, Brooklyn, New York, 1921–22. Since none of these positions seemed to offer the opportunities he desired, Willard decided to enter the investigational field and was appointed Assistant in Research (Entomology) February 1922 in the New York State Experiment Station, Geneva. While serving in this capacity, he used the opportunity for graduate study and was granted the degree of M.S. in entomology, 1925, by Cornell University. Promoted to Associate in Research 1929 and to Assistant Professor of Entomology in 1942, he became Associate Professor 1945 to 1948.

Professor Harman was a member of the following fraternal and honorary societies: Alpha Zeta, Gamma Alpha and Sigma Xi. As a member of the American Association of Economic Entomologists, he took an active part in many meetings, including those of the Eastern Branch. He traveled extensively in the United States and in the West Indies.

Investigations for the control of various fruit insects constituted his chief research efforts. These included the following pests: codling moth, eyespotted bud moth, cranberry root worm injury to apples, fruit tree leafroller, red-banded leafroller, San Jose scale, peach cottony scale and currant



SAMUEL WILLARD HARMAN

aphid. Most of the studies were with the codling moth and the development of spray programs for its control in which he became one of the leading authorities and was highly regarded by the apple growers of the state. His field experiments were well planned and conducted with great care. His success was secured more through attention to important details rather than any spectacular new methods developed or new insecticides introduced. In other words, he was able to prove to growers that attention to details of application would produce good results even with materials which are now recognized as inferior but which, at the time, were the best known.

He was very industrious, planned his investigations carefully, interpreted the data and observations astutely and presented his results and conclusions in a direct, logical manner. Numerous station bulletins and papers in this JOURNAL were published by him, his list of titles reaching a total of 60. All have a direct and concise style and many are well illustrated with graphs and photographs. Willard was in great demand as a speaker at local meetings of apple growers and at the New York State Horticultural Society. Having a direct and convincing style, free from pompous phraseology and unfamiliar words, his presentation was very acceptable and convincing to his audience. Of strict integrity, free from hypocrisy and pretence, he had those sterling qualities which all of us admire in a man of high standards. Being an outdoor enthusiast, he was a student of nature, preferring when possible to live outside of cities and towns. He was keenly interested in hunting, fishing, and camping. He was devoted to his family, had many friends and took an active part in efforts directed toward community betterment. In his passing, entomology has lost an excellent worker and his friends and associates will miss his genial smile and pleasant companionship.

F. Z. HARTZELL

BENJAMIN G. PRATT

Benjamin G. Pratt 1862-1947

B. G. Pratt, one of the Insecticide Industry's oldest pioneers, died at his home in Hackensack, New Jersey on April 26, 1947, in his eighty-sixth year.

Mr. Pratt was born in Hillsboro, North Carolina, March 24, 1862. He was the son of the Reverend Henry B. Pratt and Jonie G. Pratt. Several of his early years were spent in Colombia, South America where he helped his father who was a Missionary of the Presbyterian Church in that country. On his return to the United States he started his business career, first as a clerk in Winnsboro, South Carolina, later engaging in the soap business in the South and Southwest. Still later he went to New York and developed his interests in soluble oils which he retained through the remainder of his long life.

During this period he was visited by Professor John B. Smith, Entomologist of the New Jersey Agricultural Experiment Station who proposed that Mr. Pratt develop a soluble oil which might be used for the control of the San Jose scale, at that time the most serious pest of the fruit industry throughout the country. The result of this conference was the development of *Scalecide*, possibly the first proprie-

tary insecticide to establish a permanent standing among the commercial insecticides, still widely used for its original purpose.

Mr. Pratt had a sincere belief in the value of his product to the user and did a vast amount of what would now be called extension work among entomologists, fruit-growers and others to promote the use of the oil. That his efforts resulted, directly and indirectly, in a great amount of benefit to fruit-growing and to economic entomology, can not now be doubted. While Mr. Pratt did not always sell his product he never failed to sell himself.

Mr. B. G. Pratt, with his brother, now deceased also, founded the B. G. Pratt Company in 1906. Mr. B. G. Pratt retained the presidency of the company for 41 years, until his death in 1947. During this period it prospered and expanded, creating and establishing a number of new products and establishing itself in a prominent position in the insecticide industry. His son, B. G. Pratt, Jr., has succeeded him in the presidency of the company and is associated with other members of the family in the business. These include two nephews, Henry G. Pratt, Jr., a son of the other founder, Henry C. Pratt, and Robert W. Heuer and Mr. James I. Shafer, all of whom have been associated in the business for many years.

Mr. Pratt was one of the earliest members of industry to become a member of the American Association of Economic Entomologists. He was a faithful attendant at the annual meetings and befriended many a struggling young entomologist to whom his lovable personality and patently sincere interest in the problems of entomology and of entomologists greatly endeared him.

Comparatively few of the present members of the Association belonged before Mr. Pratt became a member but large numbers of them met him later and enjoyed his friendship. All who knew him appreciated him in direct proportion to the opportunity they had enjoyed to become thoroughly acquainted. They appreciated his sincerity and kindliness, his faith in his product, which was absolute. They realized that his desire to extend the use of his product was not, primarily, to make money for the company but to get as many people as possible to profit by its virtues. He was personally the most modest and unassuming of men. He flattered young entomologists, with entire sincerity, by deferring to their great supposed knowledge and ability.

Once in a while a few of us would stumble onto some information about his private charities from other sources. It would not be proper to detail any of these but from them some of us came to feel that we knew the real B. G. Pratt and by reason of them his memory will be cherished by those who were fortunate enough to know the real man as well as by the numerous others who did not have the glimpse behind the screen which hid his charities and his real character.

In his later days Mr. Pratt was able to relax and shift some of the burdens onto others. As a result he was the oldest young man, or the youngest old man in the Association. The writer remembers a recent meeting where Mr. Pratt gave him a most entertaining account of an airplane trip over a large part of the continent of Africa. He told of this with the zest and enthusiasm which showed no indication of any decadence of his mental faculties even though he was then past eighty, if memory is not at fault.

We have lost a man, a citizen and a friend of entomology and entomologists. But we may rejoice that to one so worthy was granted a life span so long and so richly appreciated.

Arthur Gordon Ruggles 1875-1947

Arthur Gordon Ruggles, Professor Emeritus of Entomology and Economic Zoology at the University of Minnesota, and for twenty-five years State Entomologist, died December 23, 1947 in Professional Center hospital, Montgomery, Alabama, at the age of seventy-two years. Since his retirement his home had been in Union Springs, Alabama.

Mr. Ruggles was born May 30, 1875 in Annapolis Royal, Nova Scotia. He graduated from the Truro, N. S., Normal School and from the Truro Agricultural School. After teaching for a time in the Provincial schools, he entered the College of Agriculture of Cornell University and was granted the B.S.A degree in 1901. His graduate work in Entomology was interrupted but he returned to complete his work for the A.M. degree in 1904.

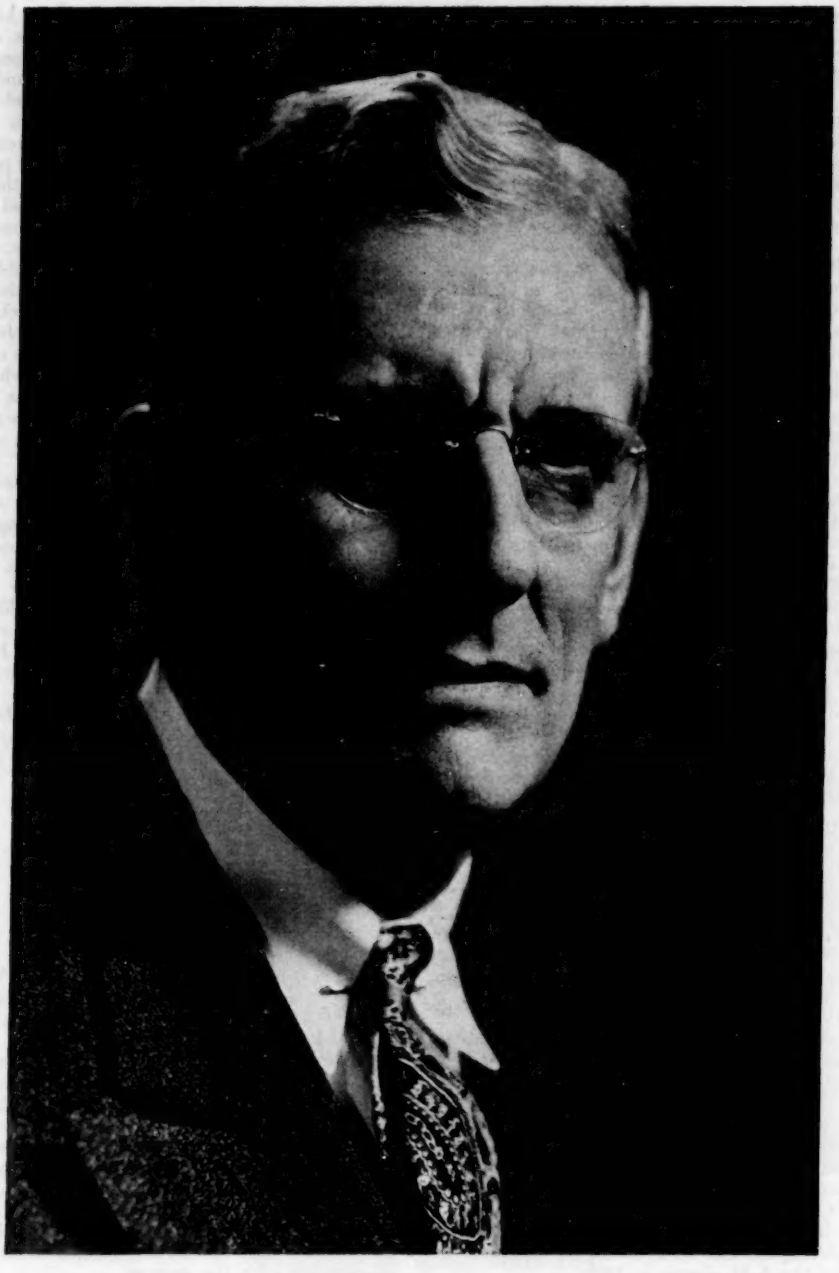
In 1902 he joined the staff of the University of Minnesota where he remained for forty-one years, first as assistant professor of Entomology and assistant to the State Entomologist (1902–13), then associate professor (1913–18), professor and, succeeding F. L. Washburn, State Entomologist (1918–43). During the year 1912–13 he served as entomologist of the Pennsylvania Chestnut Blight Commission. In 1940–41 he was chairman of a committee requested by the Bureau of Entomology and Plant Quarantine to evaluate the work on control of the gypsy moth.

Professor Ruggles was an outstanding teacher who was ever ready to aid his students in their problems, whether scholastic or personal. Many of the leaders in agriculture throughout the state recall with deep appreciation their contacts with him during their student days.

Responsible for details of regulatory work as he was almost from the beginning of his appointment at Minnesota, his approach was primarily that of an educator rather than as an officer of the law. Genuinely interested in the problems and frank and open in his approach he won the cooperation of those with whom he had to deal. This was manifest in his enforcement of the State Nursery Inspection laws, in the development of the bee inspection work and in the orchard clean-up campaign which he initiated in cooperation with the growers.

Professor Ruggles was a member of the A.A.A.A., American Association of Economic Entomologists of which he served as president in 1923, the Entomological Society of America (serving as first vice-president 1937), and Permanent President of the International Great Plains Entomological Conference from 1935 to 1946. He had a genuine love for growing plants and was an active member of the State Horticultural Society.

He published numerous papers in the JOURNAL OF ECONOMIC ENTOMOLOGY and in various agricultural and horticultural journals but his chief contribu-



ARTHUR GORDON RUGGLES

tions were in the form of timely bulletins and circulars of the Minnesota Agricultural Experiment Station and in the Reports of the State Entomologist. As a colleague Arthur Ruggles was always consulted on departmental matters for his prime consideration was the best interest of the department rather than sectional or personal. Through his friendly nature, his live interest in entomological problems, and his cooperative spirit he won a host of friends who mourn his departure.

JOURNAL OF ECONOMIC ENTOMOLOGY
Official Organ American Association of Economic Entomologists

Vol. 41 October, 1948 No. 5

The Doctor's Degree

In an address on "The Future Training of Entomologists," given before the teaching section at the Dallas meeting in 1945, I presented a table from the registrations in the National Roster, giving the highest attained degrees of registrants in certain biological specializations. A comparison of the number of registrants having the Ph.D. in Entomology with the percentages of other specializations in the field of the biological sciences supported the statement made in the address that "our profession is not particularly impressive in its academic preparation."

Table 1.—Registrations in the National Roster in the biological fields on December 31, 1945, showing highest degrees attained by the registrants. Percentages are to nearest whole numbers.

Professional Field	Per Cent Doctors	Per Cent Masters	Total Registrations
Biological and Agricultural Sciences			23886
Agronomy, Soil Science	18	25	2221
Anatomy	73	13	473
Animal and Poultry Sci.	10	27	1201
Bacteriology and Immunology	28	24	2593
Botany	56	29	1041
Dairy Science	10	23	1158
Entomology	31	35	1526
Forestry, Range Mgt.	3	23	4383
General Biology, Natural History	21	24	1917
Genetics	67	21	371
Horticulture	23	32	1115
Human Nutrition	29	32	435
Parasitology	61	23	316
Pathology	15	17	640
Pharmacology	52	15	306
Physiology	65	17	840
Plant Pathology	56	28	708
Plant Physiology	74	20	330
Wildlife and Fish	21	36	397
Zoology	46	28	1490
Other Biological and Agricultural Sciences	19	19	425

Note in table 1 that of the 1526 registrants in entomology only 31 per cent had a doctor's degree, while 46 per cent of 1490 registrants in zoology, 56 per cent of 1041 Botanists, 56 per cent of 708 plant pathologists, 73 per cent of 473 anatomists and 74 per cent of 330 plant physiologists had received the doctor's degree. The percentages for the master's degree or beyond, but short of the doctorate, is in inverse order, ranging from 35 per cent for entomologists to 13 per cent for the anatomists having the master's as their highest degree.

While it is not known whether the 1526 entomologists included represent a true random sample, at least the registration was not controlled or purposely slanted in any direction. It should be stated that the registration in entomology included some plant inspectors and similar employees, while the total for bacteriology included some public health and hospital laboratory employees whose claims as professionals in the fields were accepted, however, after consideration by the Roster qualifications staff. The size of the totals justifies a consideration of the significance of the differences. Furthermore, this is the only known source of information on this subject.

Are we to conclude that entomology is a relatively elementary subject and, therefore, does not require the academic preparation now attained, for example, in zoology, botany and plant pathology as representing the fields most closely related to our own? I do not think so. We teachers of entomology consider the subject to be as highly technical and quite as difficult as any of the other biological fields or specializations.

It is, of course, easy to criticize some Ph.D. degrees and to find fault with many of us who hold that degree. No degree is a guarantee that a certain definite amount of knowledge has been acquired. There are many persons not having the Ph.D. degree who "know more" than those who have it. The requirements for advanced

degrees are fairly uniform in most respects. The master's degree generally requires a year's work beyond the bachelor's, while the doctor's requires the equivalent of two additional years. Whether the candidate is average or brilliant, the instruction mediocre or superior, most persons profit from the courses, laboratory work, associations and discipline of academic work in proportion to the time spent. It is generally believed by most entomology teachers that for the bachelor's work the student builds his background of understanding and decides upon a major. The master's degree represents the beginning of specialization and the doctorate carries that specialization to the generally accepted academic peak.

Why haven't more entomologists continued their training to the Ph.D. degree? Because employers of entomologists accept candidates with less education and fail to reward adequately those who have the greater training. Whenever more employers limit consideration of applicants to holders of the Ph.D. degree or provide a salary differential in favor of the greater academic training, then young men will consider more seriously working for the doctorate. Actually, employers have not insisted on maximum academic training. In this matter, they have paid little attention to the various reports of the committees on the training of entomologists.[1]

Common explanations for the relatively low percentage of Ph.D.'s in entomology are two; namely, (1), The great majority of positions do not require Ph.D. training. This is particularly true of many Civil Service and industrial positions. (2), It has been easy for young men with little or inadequate academic training in entomology to get positions in the field. For the whole historic period of the subject in the United States, only during the period of the depression in the 30's has it been difficult to find positions in the entomological field.

Most students are expecting entomological employment soon to be more difficult to find and more competitive. There appears to be an increasing desire on the part of students (especially veterans) to continue in training for advanced degrees. Institutions also are giving more thorough and more advanced training to their entomology majors. For several years, the Department of Entomology at Kansas State College has required a minimum of 9 semester hours of entomology, 8 of Zoology, 8 of Botany and Plant Pathology, 10 of Chemistry and Physics, 3 of Bacteriology, and general competency in Mathematics and English before the student begins his work for the advanced degree. He is required to make up any deficiencies without credit towards his degree. Before many years, probably the minimum background preparation in Entomology can be raised to 12 or 15 semester hours (4 or 5 three-credit courses) before course credits begin to count towards the 30 hours for the master's degree of the 90 hours for the doctor's degree. This means that both master's and doctor's candidates are today receiving broader and more intensive training in their specialization than was the case even 5 or 10 years ago.

Naturally, one thinks of the cost of completing graduate work as well as the loss of income while so engaged. The number of assistantships, scholarships and fellowships, which are well known aids to graduate students, appear to increase each decade. Presently, the governmental assistance to veterans is enabling many to complete their studies. So the new crop of graduates in general have continued their academic training longer than the former ones. Add to this the "on the job specialization" and the experience which some apologists say is better than the classroom, a better trained, better educated and better prepared group of young entomologists is destined to furnish our successors. This development, if it becomes widespread, will in time bring the academic training of entomologists up to the highest attained in related fields.

Of course, the obvious rebuttal argument is that "on the job training" is the phase which actually equips incumbents to do their particular work satisfactorily. But no amount of "on the job training" takes the place of basic professional training. Academic training presupposes "job specialization" after an appointment, but experience in plant pathology, zoology and the other fields given in the table is believed to be just as important as in

[1] JOUR. ECON. ENT. 24(1): 27–31. Feb. 1931. Drake, Carl J. Teaching and training in the field of Entomology. JOUR. ECON. ENT. 29(1): 27–36. Feb. 1936.

entomology and those specializations appear to have a higher percentage of Ph.D.'s.

The difficulty in writing on this subject is that some not having the Ph.D. degree are over-sensitive about it and even resent discussions concerning it. This account is not written for older established specialists in the profession who could not afford the time now to take an advanced degree and probably would profit little or not at all, either professionally or financially, from the degree or the work. It is written for the younger men now either engaged in their preparation or who have lately taken positions in Entomology. It is not too late for them to aim at the maximum of preparation in the hope that they and their comrades will some day elevate the standing of entomology to the top among all of the professions.

ROGER C. SMITH

PROCEEDINGS OF THE THIRD ANNUAL MEETING

NORTH CENTRAL STATES BRANCH
AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

Hotel Pere Marquette, Peoria, Illinois, March 25-26, 1948

The third annual meeting of the North Central States Branch AAEE was held in Peoria, Illinois March 25–26. Dr. H. M. Harris of Ames, Iowa, presided over the two-day session. Dr. P. O. Ritcher of Lexington, Kentucky, was vice-president for the 1948 meeting.

The only guest speaker was Mr. S. A. Rohwer, B.E.P.Q., who brought greetings from the parent association. Outside of two short business sessions the only other general gathering of the group was for the Section on Insecticides, presided over by C. W. Kearns. Other sections and the respective chairmen were:

Cereal Insects	—J. H. Bigger
Forage Insects	—R. T. Everly
Man & Animal Insects	—R. J. Dicke
Fruit Insects	—Ray Hutson
Vegetable Insects	—J. P. Sleesman
Beekeeping	—R. L. Parker & W. A. Price
Extension	—H. Gunderson & F. G. Butcher
Forest Entomology	—H. A. Bess

The excellent program was arranged by the following committee: J. H. Lilly, Chm., R. H. Davidson, G. D. Jones, and W. T. Emery.

The committee on local arrangements was composed of H. B. Petty, Chm., H. L. Chada, and W. R. Horsfall.

The 1948 banquet was held in the ballroom of the Pere Marquette Hotel Thursday, March 25. Following the banquet, Mr. Frank Wallace, State Entomologist of Indiana, gave a very interesting and humorous travelogue on the State of Indiana. Mr. Wallace's talk was accompanied by an excellent series of Kodachrome slides.

Thursday, March 25

The meeting was called to order by President Harris at 9.00 A.M. REPORT FROM THE CONSTITUTION REVISION COMMITTEE, given by Chm. G. C. Decker.

The following change in the Constitution was proposed and approved unanimously by the members.

That Section 3 of Article III be stricken and replaced by the following:

(a) A committee to nominate officers to be elected at the next annual meeting shall consist of three members receiving the largest number of votes in a written poll following nominations from the floor at each annual meeting. This committee shall also constitute the election officials.

(b) At the ensuing annual meeting the nominating committee shall propose 2 names for each elec tive office. Nominations from the floor shall be in order.

(c) Officers for the ensuing year shall be those nominated members receiving the largest number of votes in a written poll taken at the time of the meeting.

The following addition to the By-Laws was pro posed and approved unanimously.

Article III Section 5.

The Recorder shall be responsible for compiling, editing and publishing the proceedings of the general meetings and shall mail same to a list supplied by the Secretary-Treasurer. (Addition) The Recorder is to receive a stipend of twenty-five dollars for his time and effort in the preparation of the proceedings.

The following committees were appointed by President Harris:

Resolutions	*Time and Place of 1949 Meeting*
Ray Hutson, *Chairman*	C. R. Neiswander, *Chairman*
H. C. Severin	E. Hixson
D Questel.	G. E. Gould

Auditing
C. E. Mickel, *Chairman*
A. M. Vance

The membership elected the following officer-selecting committee by written ballot:

Ray Hutson
H. O. Deay
Wm. P. Hayes

Session adjourned at 9.45 A.M.

Friday, March 26

The meeting was called to order by President Harris at 1.30 P.M.

The first business was the appointment of R. A. Blanchard as recorder for the year 1948.

In accordance with the new amendment to the constitution approved during the first business session, President Harris called for the election of a three-man nominating committee to serve for the 1949 meeting. The following men were nominated to this committee, whereupon the nominations were closed.

L. L. English
Roger Smith
L. F. Steiner

Treasurer's Report

March 19, 1947–March 24, 1948

Credits

Balance in Treasury, March 19, 1947	$ 65.20
1 copy 1946 Proceedings	2.00
225 copies 1947 Proceedings	450.00
1 copy 1948 Proceedings (J. E. Bussart)	2.00
From Am. Assoc. of Econ. Entomologists for 1947 meeting expenses	39.03
Bank Interest to Jan. 1, 1948	2.45
Check Exchange	.05
Total Credits	$560.73

Debits

Banquet ticket B. P. Uvarov, 1947 meeting	$ 2.55
Rental of P. A. System, 1947 meeting	12.50
Deficit during 1947 registration	1.00
Paid to J. S. Houser for phone calls and stamps	7.52
Mimeographing & mailing 1947 program	19.01
Letter to membership	13.24
Birthday greetings to L. O. Howard	1.28
Funeral spray for J. S. Houser	9.00
Preparation and mailing 1947 Proceedings	162.54
Letter to membership	10.83
Rubber stamp and supplies	4.66
Total Debits	$244.13
Balance	$316.60

REPORT OF AUDITING COMMITTEE

Treasurer's report was examined and found correct, March 25, 1948.

Clarence E. Mickel
Arlo M. Vance

Report approved by membership.

REPORT FROM RESOLUTIONS COMMITTEE

1. Resolved that the North Central States Branch of the American Association of Economic Entomologists extend to the Peoria Association of Commerce and the Hotel Pere Marquette our thanks for their efforts in arranging accommodations for the 1948 meeting.

2. Resolved that the North Central States Branch of the American Association of Economic Entomologists comment the officers, the executive committee, and the local committee for their untiring efforts in arranging a most attractive, practical, and timely program.

3. Resolved that the North Central States Branch of the American Association of Economic Entomologists commend the chairmen of the various sections for the efficient manner in which the various meetings were conducted.

4. Resolved that the North Central States Branch of the American Association of Economic Entomologists thank each individual who contributed to the success of the meeting by appearing on the program or participating in the discussions.

5. Resolved that the North Central States Branch of the American Association of Economic Entomologists especially thank Frank N. Wallace for his delightful Indiana travelogue.

6. Resolved that the North Central States Branch of the American Association of Economic Entomologists expresses our gratitude in having the president of the parent association in attendance and taking part in our program.

7. Resolved that the North Central States Branch of the American Association of Economic Entomologists express to the families of our Past President J. S. Houser and Prof. A. G. Ruggles our sympathy in their and our loss.

8. Resolved that the North Central States Branch of the American Association of Economic Entomologists urge all members to support the National Food and Feed Conservation Program (Office Food & Feed Conservation of U.S.D.A.).

9. Resolved that the North Central States Branch of the American Association of Economic Entomologists urge all members to exercise extreme caution before giving approval to the use of insecticides, application equipment, and practices until sufficient tests warrant such approval.

R. HUTSON, *Chairman*
H. C. SEVERIN
DAVID QUESTEL

Report approved by membership.

REPORT OF TIME AND PLACE COMMITTEE

Mr. Chairman: After considering the provisions of the constitution relative to the time and place of holding annual meetings the committee has voted unanimously to accept the invitation of the Wisconsin entomologists and the Chamber of Commerce of the city to hold the Fourth Annual Conference of the North Central States Branch of the American Association of Economic Entomologists at Milwaukee, Wisconsin on March 24 and 25, 1949.

GEORGE E. GOULD
EPHRIEM HIXSON
C. R. NEISWANDER, *Chairman*

REPORT OF OFFICER SELECTING COMMITTEE

This committee has selected the following officers for the coming year:

President—FRANK WALLACE
Vice-President—WM. G. BRADLEY
Secretary-Treasurer—J. W. APPLE

RAY HUTSON, *Chairman*
H. O. DEAY
WM. P. HAYES

Meeting adjourned at 2:15 P.M.

NORTH CENTRAL STATES BRANCH
AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

Registration—1948

ARKANSAS
Miner F. D.
Warren, Lloyd O.

CANADA
ARNOTT, D. A.
Stirrett, Geo. M.

COLORADO
McCauley, W. E.

CONNECTICUT
Gleissner, Bruce D.

DELAWARE
Fassig, Walter W.
Sharp, S. S.

GEORGIA
Bruce, W. G

ILLINOIS

Allen, Harry C.
Apple, J. W.
Bevernick, A. W.
Bigger, J. H
Blanchard, R. A.
Brower, D. G.
Bruce, Willis N.
Bussart, J. Everett
Chandler, S. C.
Cleveland, C. R
Compton, C. C.
Couch, M. D.
Dadant, M. G.
Decker, G. C.
Delaplane, Wm.
Eavis, Henry J.
Eden, W. G.
English, L. L.
Foote, R. W.
Geuther, H. W.
Gowdy, J. C
Guthrie, Frank E.
Hayes, Wm. P.
Hockenyos, Geo. L.
Horsfall, William R.
Kearns, C. W.
Knote, Chas. E.
Lewis, Dave
Ludvik, G. F.
Lynch, David W.
March, Ralph B.
Mills, H. B.
Milum, V. G.
Paullus, J. H.
Petty, H. B.
Ries, Donald T.
Roan, C. C.
Stull, Carl R.
Weinman, Carl J.
White, Chas. E.
Wright, John M.

INDIANA

Bartholomai, C. W.
Boyd, Fred T.
Brooks, Ivan C.
Campau, E. J.
Clark, James A.
Davis, J. J.
Deay, Howard O.
Fahey, Jack E.
Gould, George E.
Hannah, Paul E.
Krausche, Kenneth
McAlister, Harold J.
Osmun, John V.
Patch, L. H.
Schlosberg, Morris
Steiner, L. F.
Trippel, A. W.
Ulman, P. T.
Vance, Arlo M.
Wallace, Frank N
Walter, E. V.
Weber, Walter
Wilson, M. Curtis

IOWA

Barakat, John S.
Brayton, Bert O.
Chada, Harvey L.
Griffin, Robert H.
Gunderson, Harold
Hagen, Vern S.
Hardy, D. Elmo
Harris, H. M.
Jaques, H. E.
Jarvis, K. H.
Mitchell, Wallace C.
Park, O. W.
Rorman, Wayne D.

KANSAS

Butcher, Fred D.
Calkins, L. A.
Dahm, Paul A.
Emery, Walter T.
Frankenfeld, J. C.
Parker, R. L.
Smith, Howard W.
Smith, Roger C.
Stansbury, Roy

KENTUCKY

Price, W. A.
Ritcher, Paul O.

MARYLAND

Poos, F. W.

MICHIGAN

Dieter, Curtis E.
Fletcher, Fred
Graham, S. A.
Hutson, Ray
Janes, Ray L.
Lynn, G. E.
McCarthy, Geo. H., Jr.
Morofsky, W. F.
Rogers, J. Speed

MINNESOTA

Aamodt, T. L.
Harris, H. H.
Mickel, Clarence E.

MISSOURI

Adams, Lloyd E.
Beaver, B. F.
Craig, Wilfred P.
Cuff, Ray
Goff, Corbin C.
Hatfield, Ira
Hinkle, Galen A.
Hyry, Edmund C.
Jenkins, Lee
Jones, George D.
Kennady, John W.
Malone, M. S.
Magner, J. M.
Portman, Roland W.
Swisher, E. M.
Wehrmann, Robert H.
Wingo, Curtis W.

NEBRASKA

Barakat, Edward S.
Bare, O. S.
Gates, L. M.
Hill, Roscoe E.
Hixson, Ephriam
Lomax, Jack W.
Sooter, Clarence A.
Walstrom, R. J.

NEW HAMPSHIRE

Farrar, M. D.

NEW JERSEY

Alexander, C. C.
Ferguson, George R.
Heal, Ralph E.

NEW YORK

Adams, J. F.
Dye, H. W.
Glass, E. H.
Sanders, J. G.

NORTH DAKOTA

Butcher, F. Gray
Munro, J. A.

OHIO

Batchelder, C. H.
Bewick, L. F.
Bradley, Wm. G.
Brunn, L. K.
Dean, John G.
DeLong, D. M.
Dicke, F. F.
Everly, Ray T.
Irons, Frank
Neiswander, C. R.
Neiswander, R. B.
Polivka, J. B.
Questel, David D.
Rings, Roy W.
Sleesman, J. P.
Sutton, Robert
Weyl, Val E.

OKLAHOMA

Dahms, R. G.

PENNSYLVANIA

Brandes, Gordon A.
Brunton, J. G.
Guy, H. G.
Miller, A. C.
Walker, Harry G.

SOUTH DAKOTA

Lyons, Thomas R
Severin, H. G.

TEXES

Clark, S. W.
Hare, Quinton A.

WASHINGTON, D. C.

Annand, P. N.
Baker, Howard
Baker, W A.
Hall, David G.
Jones, M. P.
Knipling, E. F.
Rohwer, S. A.

WISCONSIN

Bess, Henry A.
Carroll, Francis E.
Chamberlin, T. R.
Chambers, E. L.
Chapman, R. K.
Dicke, Robert J.
Dobson, R. C.
Dudley, J. E., Jr.
Ferguson, William C.
Fisher, E. H.
Lilly, J. H.
Shenefelt, Roy D.
Voss, Carrol M.
Whipp, Arthur A.

WYOMING

Robb, Theodore R.

J. W. APPLE
Secretary-Treasurer

PROCEEDINGS OF THE THIRTY-SECOND ANNUAL MEETING

PACIFIC SLOPE BRANCH AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

Hotel Vancouver, Vancouver, British Columbia

The thirty-second annual meeting of the Pacific Slope Branch was held at Vancouver, B. C., June 14, 15, and 16, 1948. Headquarters and all sessions were at the Hotel Vancouver. This was the first meeting of this Branch held in Canada, and it was undoubtedly the best meeting we have ever had.

The Canadian entomologists, insecticide men, and their wives went to a great deal of effort in making arrangements for the meeting and entertaining those in attendance. On Sunday night there was an informal get-together, on Monday a delightful evening cruise on Howe Sound, and finally a dinner-dance and marvelous floor show on Tuesday night. For the ladies there was an afternoon sightseeing tour, and a luncheon at the Royal Vancouver Yacht Club.

A very fine technical program was presented, with a total of 52 papers, including 6 invitational papers and 3 informal talks.

The regular sessions were opened with an address of welcome from Professor Spencer of the University of British Columbia, and a response by Chairman O'Neill, followed by some informal remarks by President Rohwer. There was one symposium on "New Insecticides" and one on "Mites Attacking Agricultural Crops." Other sessions were taken up with papers on various phases of economic entomology, and most of them included information on the uses of the newer insecticides.

Committees appointed at the opening session reported at the final session. All reports were accepted by unanimous vote.

TREASURER'S REPORT

1947–48

	Received	*Paid Out*
Balance in bank, June 20, 1947	$ 47.67	
Registration fees at Berkeley meeting	295.00	
June 23, 1947, Rent of Screen		$ 9.00
June 25, 1947, telegram to Dr. Howard		3.00
June 25, 1947, rent of room at Claremont Hotel		50.00
July 30, 1947, interest on bank account	.29	
Aug. 22, 1947, postage stamps		5.00
Aug. 22, 1947, balance from Entertainment Fund, at Berkeley meeting	251.52	
Mar. 15, 1948, telegram to Dr. Cory		1.26
Dec. 31, 1947, interest on bank account	2.53	
Mar. 25, 1948, printed checks for P.S.B.		1.35
Mar. 6, 1948, notices of Vancouver meeting		81.13
Apr. 13, 1948, card index of members		7.85
Total expense		$158.59
Balance in bank, June 6, 1948		438.42
	$597.01	$597.01

ROY E. CAMPBELL, Treasurer

June 14, 1948, Audited and approved by:

Leo R. Gardner
Esler Johnson
E. J. Newcomer, *Chairman*
Auditing Committee

REPORT OF NOMINATING COMMITTEE

Chairman.....J. N. RONEY, *Phoenix, Ariz.*
Vice-Chairman:.....
.....H. M. ARMITAGE, *Sacramento, Calif.*
Secretary-Treasurer:.....
.....ROY E. CAMPBELL, *Alhambra, Calif.*

A. E. MICHELBACHER
LEROY CHILDS
H. S. TELFORD
A. J. FLEBUT, *Chairman*

REPORT OF RESOLUTIONS COMMITTEE

On the occasion of this first meeting in Canada of the Pacific Slope Branch of the American Association of Economic Entomologists, we are again reminded of the wisdom of our forefathers on both sides of the border who forsook the customs of the past and resolved that this boundary should not be a barrier, but rather a mighty bridge which men of good will could freely cross and recross as they wished. We enjoy the fruits of their wise planning, for here, as almost nowhere else on earth, the cheerful greeting has replaced the sentry's challenge. In a troubled world our harmonious relations are a living proof that where the people are free they are always friendly.

We wish to commend the local committees for the painstaking care with which they have anticipated and provided for every requirement of the meeting. Especial thanks are due them for the unusual features of the entertainment and for the hospitality shown to the wives and families of many of our members. The members of these committees who are responsible for these arrangements are as follows Canadian Committee on Arrangements: James C. Barr, Chairman; L. M. Godfrey, Arthur Laing, Walter A. Leckie, C. McLean, H. F. Olds. U. S. Committee on Arrangements: Wm. J. F. Francis, Chairman; R. S. Braucher, Ed. Littooy, C. E. Graves. Ladies Committee: Mrs. Arthur Laing, Chairman; Mrs. James C. Barr, Mrs. Walter Leckie, Mrs. H. F. Olds, Mrs. G. P. J. Parish. Program Committee: E. J. Newcomer, Chairman; G. E. Carman, W. M. Hoskins, James Marshall, H. E. Morrison, G. F. Knowlton, G. J. Spencer.

To the management of the Hotel Vancouver we wish to express our appreciation of the comfortable rooms provided for the various activities.

We keenly appreciate the generosity of various members and business firms of the insecticide industry in arranging for enjoyable entertainment, which has added greatly to the pleasure of this meeting.

The attendance of the National President of the Association and his inspiring message have reminded us that we are a part of a larger organization and that our problems, our successes, and even our failures all contribute to the progress of our science. To President Rohwer we extend our sincere thanks.

Lastly, we send greetings to all our members who have not been able to attend and we hope that they may be able to renew the bonds of fellowship at our next meeting.

A. M. BOYCE
A. F. KIRKPATRICK
W. N. HOSKINS, *Chairman*

REPORT OF COMMITTEE TO SELECT MEETING PLACE IN 1949

This committee recommends that the meeting in 1949 be held at Grand Canyon, Arizona, during the third week in June, the exact dates to be arranged later with the hotel management.

GLEN E. CARMAN
J. F. KAGY
CHARLES DOUCETTE
J. N. RONEY, *Chairman*

A total of 234 persons registered, and the following members were present:

MEMBERS AND VISITORS IN ATTENDANCE
(Names of members starred)

Paul B. Allen,* General Chemical Co., Yakima, Wash.
H. Andison, Dept. of Agr., Victoria, B. C.
H. W. Arrowsmith, American Cyanamid Co., San Francisco
W. Besler, Besler Corp., Emeryville, Calif.
A. E. Bonn,* Van Waters & Rogers, Seattle, Wash.
S. F. Bailey,* Univ. of California, Davis
James C. Barr, General Chemicals, Ltd., Vancouver
F. R. Barron, American Cyanamid Co., Arcadia, Calif.
J. Alvin Bernhard, Westvaco Chem. Corp., Newark, Calif.
C. J. Boissonou,* Shell Oil Co., Oakland, Calif.
G. T. Bottger,* U.S.D.A., Anaheim, Calif.
A. M. Boyce,* Univ. of California, Riverside
D. H. Brannon, Washington State College, Pullman
R. S. Braucher,* Dow Chemical Co., Seattle
Art Bronson,* Richfield Oil Corp., Los Angeles
Frank A. Brown, Colloidal Products Co., San Francisco
E. R. Buckell, Dom. Ent. Branch, Kamloops, B. C.
W. H. Burnside, Hercules Powder Co., Wilmington, Del.
R. W. Burrell,* U.S.D.A., Yakima. Wash.
J. E. Bussart,* Velsicol. Corp, Chicago, Ill.
R. W. Clark, Clark Feed & Seed, Bellingham, Wash.
D. J. Carse, Canadian Industries, Ltd., New Westminster, B. C.
R. Craig,* Univ. of California, Berkeley
C. R. Cunningham, Dom. Dept. of Agr., Vancouver, B. C.
Alvin J. Cox,* Emeritus, Chief, Calif. Bur. of Chem., Palo Alto
O. T. Coffin, Swift & Co., Los Angeles
L. V. Clegg, Canadian Industries, Ltd., New Westminster, B. C.
S. W. Clark,* Texas Gulf Sulphur Co., Houston, Texas
M. W. Choate,* Sherwin-Williams Co., Yakima, Wash.
Leroy Childs,* Oregon State College, Hood River
G. E. Carman,* Univ. of California, Riverside
D. J. Chamberlin, Jr., Shell Oil Co., Seattle
Roy E. Campbell,* Secretary, Pacific Slope Branch, Alhambra, Calif.
J. J. Degryse, Dom. Dept. of Agr., Ottawa, Ontario
Chas. Doucette,* U.S.D.A., Sumner, Wash.
Clare D. Dolman, Industrial Chemist, Seattle
G. M. Darling, Van Waters & Rogers, Inc., Seattle
Charles Duggan, Charles Duggan Co., Los Angeles
S. C. Dorman,* Shell Oil Co., Modesto, Calif.
D. G. Denning, Univ. of Wyoming, Laramie
Edward Degginger, Julius Hyman & Co., San Francisco
L. W. Davis, Swift & Co., Portland, Ore.
A. W. Evans, Dupont Company, Corvallis, Ore.
E. O. Essig, Univ. of California, Berkeley
A. M. Esberg, Eston Chemicals, Inc., Los Angeles
R. D. Eichmann,* Stauffer Chemical Co., Pullman, Wash.
F. F. Ferguson,* University of Washington, Seattle
R. W. Finch, Swift & Co., Los Angeles
L. H. Foster, Commercial Chemicals, Ltd., Vancouver
D. P. Furman,* Univ. of California, Berkeley
Wm. J. F. Francis,* Penn Salt Mfg. Co., Tacoma, Wash.
G. W. Fletcher, Monsanto, Canada, Ltd., Vancouver
A. J. Flebut, Niagara Chem. Co., Berkeley, Calif.
S. E. Flanders, Univ. of California, Riverside
Harry G. Fulton, Dom. Expt. Lab., Agassiz, B. C.
F. A. Gunther, Univ. of California, Riverside
C. E. Graves, Dupont Company, Tacoma, Wash.
Lang Godfrey, Canadian Industries, Ltd., New Westminster, B. C.
Lorin L. Gillogly,* State Dept. of Agr., Sacramento, Calif.
L. G. Gentner,* Oregon State College, Medford
L. W. Garner,* Pacific Guano Co., Berkeley, Calif.
Leo R. Gardner, Calif. Spray Chem. Corp., Berkeley
Harold Harms, Canadian Industries Ltd., New Westminster, B. C.
L. W. Hanna,* Birdseye Snider Div., Hillsboro, Ore.
J. C. Hamilton, Plant Protection Div., Vancouver
W. N. Hoskins,* Univ. of California, Berkeley
L. F. Hosbrook, Hall Scale Eradication, Chico, Calif.
J. L. Horsfall,* American Cyanamid Co., New York
Melville H. Hatch,* Univ. of Washington, Seattle
N. F. Hardman, Stauffer Chemical Co., Palo Alto
R. H. Handford,* Field Crop Insect Lab., Kamloops, B. C.
W. J. Hamill, Wenoka Federation, Behastin, Wash.
P. Hahn, Canadian Historical Soc., Toronto, Ontario
Paul Jorgenson, Niagara Chemical Co., Mt. Vernon, Wash.
L. A. Jacobson, Dept. of Agriculture, Lethbridge, Alta.
M. P. Jones,* U.S.D.A., Washington. D. C.
Edward W. Jones,* U.S.D.A., Walla Walla, Wash.
V. B. Johnson, Dom. Dept. of Agriculture, Vancouver, B. C.
Esler Johnson,* Esler Johnson Co., San Francisco
Carl Johansen, Washington Expt. Sta., Puyallup
Lee Jeppson, Citrus Expt. Station, Riverside, Calif.
J. F. Kagy,* Dow Chemical Co., Seal Beach, Calif.
H. H. Keifer,* State Dept. of Agr., Sacramento, Calif.
E. C. Klostermeyer, Irrigation Expt. Station, Prosser, Wash.
F. A. Kirsch,* California Spray Chem. Co., Yakima, Wash.
A. F. Kirkpatrick,* American Cyanamid Co., San Francisco
K. M. King,* Dom. Dept. of Agr., Victoria, B. C.
Ray Lund, Wenoka Federation, Wenatchee, Wash.
Ed. Littooy,* Colloidal Products Corp., San Francisco
A. W. Lindquist,* U.S.D.A., Corvallis, Ore.
Allen Lemmon,* State Dept. of Agr., Sacramento, Calif.
Walter A. Leckie, Harrisons & Crossfield Can. Ltd., Vancouver
Bryan A. Langley, McLaughlin Gormley King Co., Wenatchee, Wash.
M. C. Lane, U.S.D.A., Walla Walla, Wash.
Arthur Laing, Buskersfield Ltd., Vancouver
George C. Martin, U.S.D.A., Portland, Ore.
Philip Mueller, John Powell & Co., San Leandro, Calif.
B. Mowry, Gresham Berry Growers, Portland, Ore.
D. C. Mote, Oregon State College, Corvallis

Joseph B. Moore,* McLaughlin Gormley King Co., Minneapolis, Minn.
W. J. Moody, Monsanto, Canada, Ltd., Vancouver
K. W. Montfort, North West Wholesale, Wenatchee, Wash.
A. A. Mitchell, Wenoka Federation, Wenatchee, Wash.
C. E. Miller, Colloidal Products Corp., Wenatchee, Wash.
Woodrow W. Middlekauff,* Univ. of California, Berkeley
A. E. Michelbacher,* Univ. of California, Berkeley
Neville Meyers, Dom. Dept. of Agriculture, Vancouver
R. Messum, Plant Protection Div., Vancouver
J. Merryman, Cal. Spray Chem. Corp., Mount Vernon, Wash.
J. W. Merryfield, Canadian Industries, Ltd., Vancouver
E. L. Mayer,* U.S.D.A., Anaheim, Calif.
James Marshall,* Dom. Ent. Laboratory, Summerland, B. C.
L. J. McCann, Niagara Chem. Co., Yakima, Wash.
C. W. McLean, Nichols Chemical Co., Vancouver
G. S. McMillan, Imperial Oil Co., Ltd., Loco, B. C.
F. B. McLane, Stauffer Chemical Co., Los Angeles
L. J. McIntosh, Hall Scale Eradication, Chico, Calif.
E. A. McGregor,* U.S.D.A., Whittier, Calif.
W. E. McCauley,* Julius Hyman & Co., Denver, Colo.
A. J. McGinnis, Dept. of Agriculture, Lethbridge, Alta.
Irwin Newell, Univ. of Oregon, Eugene
E. J. Newcomer,* U.S.D.A., Yakima, Wash.
R. V. Newcomb,* DiGiorgio, Fruit Corp., Yuba City, Calif.
Jack R. Neil, Sherwin Williams Co., Oakland, Calif.
H. F. Olds,* Dom. Dept. of Agr., Vancouver
W. J. O'Neill, Washington Expt. Sta., Wenatchee.
G. P. Parish, Harrisons & Crossfield Ltd., Vancouver
A. H. Phillips, Dom. Dept. of Agr., Vancouver
John C. Pritchett, U.S.D.A., Seattle
Earl Pritchard,* Univ. of California, Berkeley
S. A. Rohwer,* U.S.D.A., Washington, D. C.
Glen Rouse, Niagara Chemical Co., Yakima, Wash.
W. A. Ross,* Fruit Insect Investigation, Ottawa, Ontario
James N. Roney,* Univ. of Arizona, Phoenix
H. L. Rideout,* General Chemical Co., Wenatchee, Wash.
H. A. Richmond, Dom. Forest Insect Dept., Vancouver
E. C. Reid, Dom. Dept. of Agr., Vancouver
W. B. Rasmussen,* Sherwin-Williams Co., Oakland, Calif.
L. F. Steiner, Shell Oil Co., San Francisco
G. J. Spencer,* University of British Columbia, Vancouver
Perez Simmons,* U.S.D.A., Fresno, Calif.
George F. Sherrill, Vandyk and Co., Newport, Beach, Calif.
W. A. Shearing, Sherwin-Williams Co., Yakima, Wash.
R. D. Shannon, Food Machinery Corp., Yakima, Wash.
Roy Shanaman, Penn Salt Mfg., Co. Portland, Ore.
Frank Shanahan, Shanahan's Ltd., Vancouver
Roger Scott,* Geigy Co., Walla Walla, Wash.
E. I. Smith,* U.S.D.A., Seattle, Wash.
N. B. Seiffert, Dom. Dept. Plant Protection, Vancouver
Guy C. Sartor, Van Waters & Rogers, Inc., Seattle
O. H. Swezey,* H.S.P.A. Expt. Sta., Honolulu
A. F. Swain,* ESton Chemicals Co., Los Angeles
Stanley Strew, Chipman Chemical Co., Seattle
L. L. Stitt,* Western Wash. Expt. Sta., Puyallup
Chas. H. Starker,* Pacific Supply Coop., Portland
Ray Teerling, Besler Corp., Emeryville, Calif.
C. Tapp, Dominion Dept. of Agr., Vancouver
H. S. Telford,* Washington State College, Pullman
Chas. D. Thurmond, Monsanto Chemical Co., San Francisco
W. D. Touzeau, Dom. Dept. of Agr., Vancouver
S. E. Taylor, Rotox Ltd., Vancouver
R. Edward Trumble,* Consultant Entomologist, Wenatchee, Wash.
R. P. Watwood, Monsanto Chemical Co., San Francisco
R. L. Webster,* Washington State College, Pullman
Bernall Wilson, A. L. Castle, Mountain View, Calif.
E. J. Wolf, U. S. Insecticides Co., Seattle
G. E. White, Canadian Industries Ltd., New Westminster, B. C.
Verle Woods, Besler Corp., Omak, Wash.
W. I. Zeigler, American Cyanamid Co., Seattle
P. Zuk, Dom. Dept. of Agr., Vancouver
H. A. Dalrymple, *The Press*, Vancouver Province

1949 MEETING OF COTTON STATES BRANCH

The 1949 meetings of the Cotton States Branch of the American Association of Economic Entomologists will be held in Baton Rouge, Louisiana on January 31 and February 1 and 2, 1949. Paper reading sessions will begin promptly at 9:00 A.M. on January 31. Mr. Charles E. Smith, Department of Entomology, Louisiana Experiment Station, University Station, Baton Rouge, Louisiana, will handle all reservation requests. Those attending the convention will be housed in hotels and in dormitories at Louisiana State University. All reservations and requests should be directed to Dr. Smith immediately in order to assure proper accommodations. Members of industry throughout the nation are cordially invited to attend and participate in these meetings.